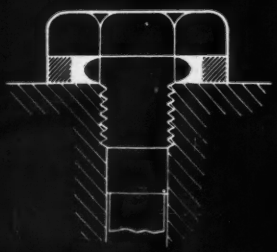
The
ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

OF MICHIGAN
MAR 1953
ENGINEERING LIBRARY

VOL. XIV No. 2. FEBRUARY, 1953

BONDED DOWTY SEALS



like this—

—where a washer must also act as a seal, a Dowty Bonded Seal will perform this dual role with maximum efficiency.

Handy for storage, Bonded Seals also provide simple fool-proof assembly and are suitable for use with either fluids or gases under a wide temperature range. Many of the standard sizes available are capable of withstanding pressures up to 10,000 lb/sq. in.

By courtesy of the Ford Motor Co. Ltd.

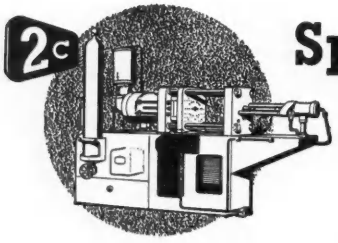
DOWTY SEALS LIMITED · ASHCHURCH · GLOS

make the most of your COPPER

with the help of the CDA...

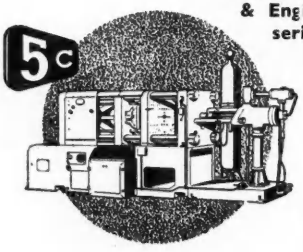
Choice of the right grade of copper or copper alloy and its use in the right way saves time, money and material. The C.D.A. exists to help you with expert advice on any of the varied uses of copper and with technical publications, obtainable on application—all free of charge.

COPPER DEVELOPMENT ASSOCIATION · KENDALS HALL · RADLETT · HERTS · TEL: RADLETT 5616



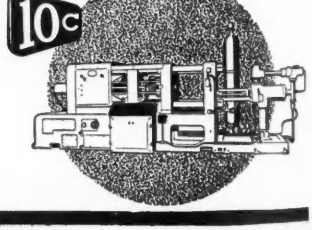
Special Announcement
ON
DIE-CASTING MACHINERY

In view of the increasing demand for castings in so many branches of industry, the Projectile & Engineering Company has designed a series of Machines which has modernized the technique of cold chamber pressure die-casting. Manufacturers will find them of the highest value for supplying an unbroken stream of perfect castings, with the minimum of labour.



The distinctive features of the PECO Die-Casting Machines include electrical control which covers every movement of the cycle and ensures continuity and uniformity of production.

Illustrated Catalogue containing full details will be gladly sent on request.



THE PROJECTILE & ENGINEERING CO. LTD.

Acre Street, Battersea, London, S.W.8

PECO PRODUCTS

Telephone : MACaulay 1212
Telegrams : 'Profectus, Claproad, London.'

CONTENTS

	Page
The Blue Pages	37
Editorial	41
Wind-Tunnel Measurements on Motor-Cycle Models	42
The Use of Castings in Airframe Design	44
Soviet Trends in Gas Turbine Development	47
The Design of Jet Ejectors	51
The " Aero-Jet Venturi " Micro-Mist Purifier	54
The Cutting of Metals with Sintered Alumina Tools	59
The Employment of Ceramic Materials for Cutting Metals	61
New Materials, Processes and Equipment	63
Classified Abstracts	67
News of the Month	69

The ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

VOL. XIV. No. 2 FEBRUARY, 1953

EDITORIAL AND ADVERTISING OFFICES:

GREAT BRITAIN
120 Wigmore Street, London, W.1.
Telephone: WELbeck 9357 & 6263

U.S.A.
366 Madison Avenue, New York 17, N.Y.
Telephone: MUrray Hill 2-8865

FRANCE
93 Champs-Élysées, Paris (8e)
Telephone: Élysées 09-03

Annual Subscription Rates:
£2 2s. 0d. in the Sterling area, $7.50 in the Dollar area.

Printed in Gt. Britain by ROBERT STOCKWELL LTD., 5-13 Baden Place, London, S.E.1, and published monthly by the proprietors, ENGINEERS' DIGEST LTD., 120 Wigmore Street, London, W.1.

pitman

Radio and Radar Technique
By A. T. STARR, M.A., Ph.D., M.I.E.E. The author is well-known as an outstanding worker in this field. In this new 830-page book he has concentrated present-day knowledge of the essential methods and techniques of radio and radar. 919 illustrations. 75/- net.

Thread Grinding and Measurement
By A. C. PARKINSON, F.I.E.D., A.C.P.(Hons.), F.Coll.H., M.Inst.Mech., and W. H. DAWNEY, A.M.I.E.I., A.M.I.Ec.E. An up-to-date manual, with useful reference material, and numerous illustrations. 21/- net.

Aircraft Instrument Design
By W. H. COULTHARD, M.Sc., A.M.I.Mech.E., F.R.P.S. A guide to the physical design principles of the standard flight instruments used in aircraft. 169 illustrations. 40/- net.

Performance and Design of D.C. Machines
By A. E. CLAYTON, D.Sc.(Eng.). A textbook for students at universities and technical schools covering the syllabuses of the B.Sc.(Eng.), the I.E.E., Higher National Certificates, and other examinations in this subject. 25/- net.

Cellulose Spraying
By JOHN HOWELL OUSBEY. A practical guide to the finishing and refinishing of automobile bodies and other metal surfaces with cellulose and synthetics. Illustrated. 10/6 net.

The Gantt Chart
By WALLACE CLARK. A complete guide to this well-known recording method, of interest to all concerned with management. Third Edition. Illustrated. 12/6 net.

Wireless Fundamentals
By E. ARMITAGE, M.A.(Cantab.), B.Sc.(Lond.). Develops the theory of radio from the fundamentals to an explanation of the superheterodyne principle. With Appendixes giving details of the more complex aspects of the subject. Illustrated. 18/- net.

Radio Upkeep and Repairs
By ALFRED T. WITTS, A.M.I.E.E. Seventh Edition. 12/6 net.
" The latest edition of this popular book can be most strongly recommended." T. & R. BULLETIN.

Mining Machinery
By THOMAS BRYSON, A.R.T.C.(Glasgow), M.E., M.I.M.S. An up-to-date Third Edition of this well-known work. 508 pages. Illustrated. 35/- net.

Handbook of Aeronautics
1. Structural Principles and Data
Published under the authority of the Council of the Royal Aeronautical Society. Fourth Edition. This is the first volume of a new edition which is fundamentally different from previous editions of this well-known handbook and contains an immense amount of up-to-date data. 336 pages. Illustrated. 45/- net.

Solution of Problems in Strength of Materials
By S. A. URRY, B.Sc.(Eng.). This new book will prove especially useful to students preparing for the B.Sc. (Engineering) Degree, and it fully covers the syllabuses of the examinations for the Higher National Certificate in Mechanical Engineering and for the Associate Membership of the professional institutions. Illustrated. 20/- net.

Steel Defects and their Detection
By HENRY THOMPSON, A.I.Prod.E., A.R.Ae.S., A.M.I.E.I. With numerous illustrations. 15/- net.
"Those whose work or interest makes them curious to know the trend of progress in the non-destructive methods of testing will find information of value."—IRON AND COAL TRADES REVIEW.

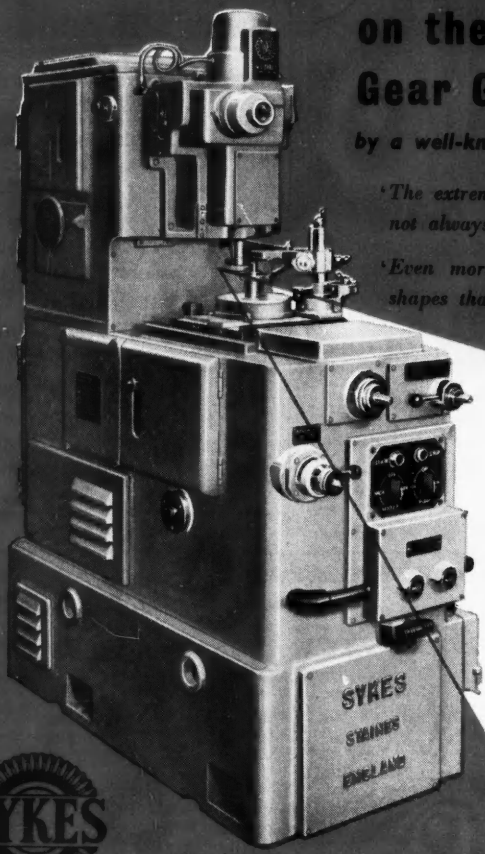
SIR ISAAC PITMAN & SONS, LTD., *Parker Street, Kingsway, London, W.C.2.*

These are some extracts from the Report on the NEW versatile V.4 Gear Generator

by a well-known Engineering Journal ★

'The extreme flexibility of this type of Machine is not always fully realised . . .'

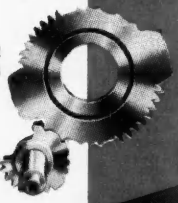
'Even more remarkable is the variety of intricate shapes that can be turned out . . .'



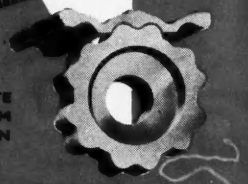
EXTERNAL HELICAL

EXTERNAL SPUR

INTERNAL SPUR & HELICAL


INTRICATE FORMS

SPUR & HELICAL RACKS


INTRICATE FORM FROM FLAT SECTION

SYKES

External and internal spur and helical gears, splines and serrations can be produced at high output rates with great accuracy, and a Rack Cutting Attachment is available for generating spur and helical racks. Furthermore, intricate shapes that could otherwise only be produced in the tool room, can be formed exactly to size as a routine operation. Set up is simple — there are no cams to change, and the controls are grouped for ease of operation.

For gears up to 4½ in. dia. and ½ in. face, and racks up to 6 ins. long

Reasonably short delivery dates are offered

★ *"Machinery Lloyd". Reprints of this Report available on request to:*

W · E · SYKES LTD

STAINES · MIDDLESEX · ENGLAND

Telephone: Staines 4281 (6 lines) Grams: 'Sykutter, Staines'

EST

THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *ABRASIVE BELT GRINDING*

The production of tapers on aluminium sheets and plates by grinding with abrasive belts has attracted considerable attention of late. Briefly, this method consists in removing large quantities of metal over wide flat surfaces at speeds hitherto thought impractical because of the danger of overheating the material. At the present time the main application of the new process is the forming of tapers in the wing sections of aircraft. But it is expected to become of greater importance in the surface conditioning of large integrally stiffened wing forgings now in course of development. Proper design of the contact wheel which presses the abrasive belt against the workpiece is stated to be one of the most important factors for successful stock removal. The large dimensions of grinders of this type will be gauged from the fact that a typical contact roll used for the grinding of aluminium is 8½ in. in diameter and 52 in. long. This roll is coated with ¾ in. of neoprene into which spiral serrations are cut. These serrations give the roll the appearance of a milling cutter and facilitate the unloading of each chip as it is cut by the grain. A grinder of this size is driven by a 100-hp motor; the peripheral speed of the contact roll is chosen as 6200 fpm when cutting aluminium and 4000 fpm when stainless steel is to be ground. The abrasive material employed for the purpose of heavy stock removal is a water-proof silicon carbide belt made of a cloth which is specially treated to resist stretching and tearing. After rough grinding, the material can be further finished by means of other belts and final surface finishes of 3 to 5 micro-inches can be attained.

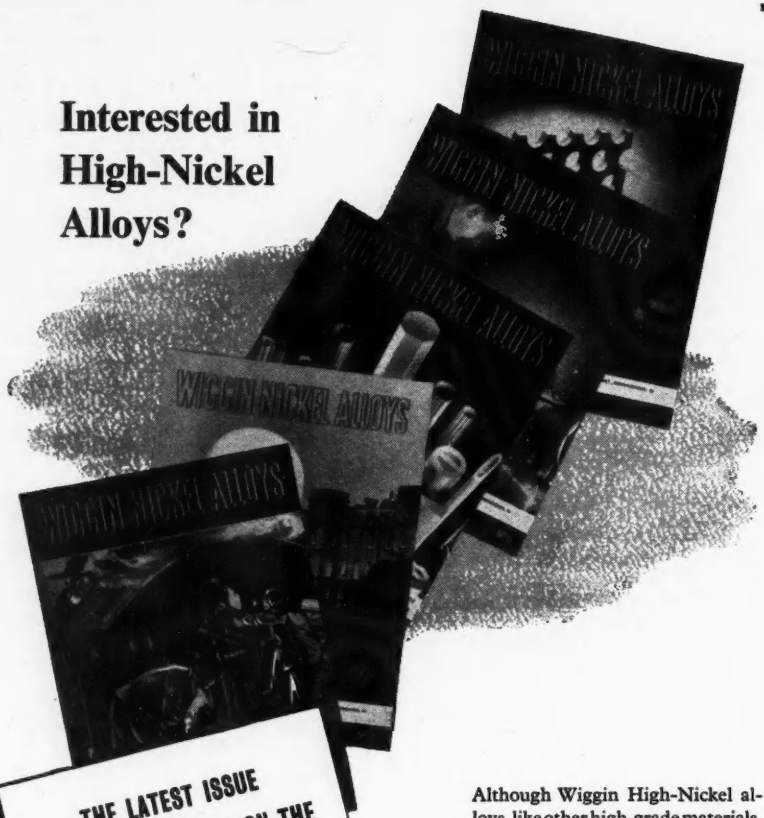
● *RUPTURE DISCS FOR QUICK PRESSURE RELIEF*

There exist many industrial operations in which it is essential quickly to relieve a system of pressure if, owing to some unforeseen event, the system pressure rises above a predetermined level. The use of rupture discs for this purpose as a quick-acting pressure relief device is well established, especially in the chemical industry. To fulfil its function in the required manner, both the dimensions of the rupture disc and the ultimate rupture strength of its material, such as bronze or stainless steel sheet, must not be allowed to vary unduly. A recent investigation was concerned with establishing rupture disc standards, based on variations in machining tolerances and shear strength. Where rupture discs are to be used to protect equipment operating at elevated temperatures, special precautions are required. It is, of course, necessary to redesign the disc on the basis of the shear strength of the material at the temperatures under which the disc will operate. The mechanical properties of an ideal rupture disc material appear to be a small plastic range, stability at elevated temperatures, reproducibility and high creep strength. The relation between the yield strength and the shear strength is also important. If the plastic range is large, the yield strength is considerably lower than the shear strength, and the disc will yield at a pressure well below the design rupture pressure. Yielding may occur as the result of intermittent pressure surges or may be continuous as in creep. Both effects will produce dimensional changes and strain hardening, which will alter the original design of the disc. A small plastic range may be obtained by either cold rolling or heat treatment, providing the alloy is heat-treatable.

● *SUBMERGED COMBUSTION IN INDUSTRIAL USE*

While submerged combustion has not attained the widespread employment for water heating originally hoped for, it is finding steadily increasing application to special purposes, where its unique characteristics prove useful. Thus, for instance, a submerged burner made of graphite is being used for burning gas in pickling baths for maintaining them at the required temperature. In an installation of this kind, the burner is placed in a special brick-lined chamber which is interconnected with the main pickling vat. Two connections are made to the pickling vessel, one near the bottom of the tank and the other near the top. When the burner is in operation, the products of combustion are released directly into the solution. The transfer of heat is direct from the gas to the liquid and is rapid and complete, resulting in high thermal efficiency. At the same time the gases bubbling through the restricted burner chamber create an air lift effect, which draws in the solution from the lower opening and causes the discharge of heated solution at the top opening. This action sets up a continuous flow within the vat which is a great aid in pickling various items, especially pipe. The circulation serves to main-

Interested in High-Nickel Alloys?



THE LATEST ISSUE INCLUDES ARTICLES ON THE FOLLOWING SUBJECTS

Monel Staybolts in Standard British Locomotives
Nimonic Alloys in the Bristol 'Proteus' Gas Turbine
Monel Pickling Crates
Nimonic Alloys in the Allen Gas Turbine
Drilling the Nimonic Alloys
Monel in Pressure and Vacuum Recorders
Monel in Steam Traps
Nimonic 90 for Springs

Although Wiggin High-Nickel alloys, like other high-grade materials, are at present in short supply, the time will come when designers will once more be able to use them in solving difficult industrial problems.

In the meantime, the articles in our technical journal show the importance of careful selection of the correct grade of material.

"Wiggin Nickel Alloys" is mailed regularly, without charge, to engineers and designers who are interested. May we send you a specimen copy?

HENRY WIGGIN & COMPANY LIMITED · WIGGIN STREET · BIRMINGHAM · 16

tain a uniform temperature throughout the pickling bath. In one typical installation comprising a vat of 38 ft length, the temperature difference in the liquor at the far end as compared to the liquor near the burner is reported to amount to no more than some 1 or 2° F. By using a submerged combustion burner, the employment of vat heating coils is, of course, entirely dispensed with.

● *IMPROVED WIRE ROPE*

The wire ropes used in cranes which handle hot metal in steel mills must be exceptionally rugged. They are exposed to the intense heat of the molten steel and at the same time are responsible for the safety of a highly valuable and potentially dangerous load. These cables are probably the most expensive ones in a steel mill, so that the length of time they can be kept in service is important both from the standpoint of safety and economy. In the past, a service life of about one year was about all that could be expected from the ropes of ladle cranes, it is reported. This was based on the use of round strand rope with either fibre or independent wire rope cores. Accurate service records are said to have proved that flattened strand wire rope lasts longer on this important and difficult application. Round strand ropes are usually discarded simply because the cross-sectional area has been reduced beyond the point of safety. Once the outer wires have lost about 36 per cent of their diameter through wear and corrosion, they become more readily displaced and subsequently broken as a result of reverse bending and general punishment. In round strand rope, the crown wire of each strand receives the greatest wear, since at first it alone can touch the sheaves. By the time the adjacent wires assume a part of the wear, the crown wire may already be dangerously worn. In flattened strand rope, each strand is keystone-shaped in cross-section and presents four wires to the sheave groove for wear instead of one. This permits longer and more even wear. The compact pattern of strands is claimed to permit a smaller core so that the rope contains 10 per cent more metal and is consequently 10 per cent stronger and safer than round wire rope of the same diameter.

● *NEW CHROMISING PROCESS*

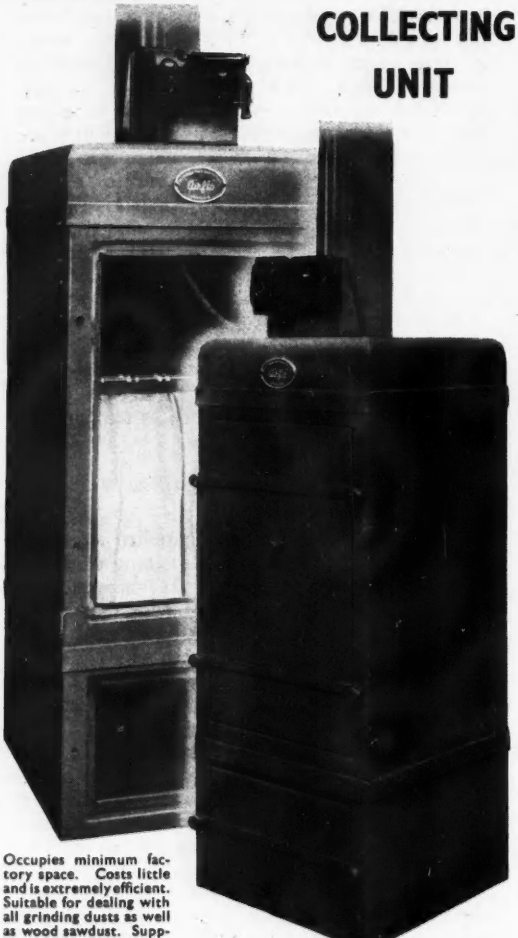
While a number of processes for the chromising of iron and steel articles have been available for some years past, application of the processes has developed preferably in fields in which the conditions of corrosion resistance are not especially stringent. That is to say, the chromising process has not yet become accepted practice in the field for which it was originally intended, i.e., in cases where the processed material should exhibit corrosion resistant properties comparable with those of the so-called stainless materials. There is no doubt that a properly chromised surface has excellent corrosion-resistant properties, equal to or at least comparable to those of a stainless material. However, great practical difficulties are encountered in producing the absolutely perfect corrosion-proof surface stratum required in such cases. No matter how good a chromised stratum may be on the average, its protective action may be worse than useless if even the slightest pinhole-size spot on the surface is left unprotected owing to some slight imperfection of the chromising process. There exists one school of thought which believes that it will be possible to attain perfection by using a salt-bath method in place of the more usual gas impregnation processes. The salt bath compositions proposed in the past were, however, handicapped by their highly corrosive attack upon the container material. A recent proposal envisages a non-corrosive bath which is described as a mixture of powdered silica with anhydrous sodium carbonate, to which chromium powder, chromium fluoride and a small amount of potassium silicofluoride are added. With such a bath, a chromium-rich alloy layer of 0·008 in. can be produced on steel within one hour, it is claimed, the process temperature being 1200° C.

● *METAL SURFACE TREATMENT WITH PEROXYGEN COMPOUNDS*

Many surface treatments as applied to metals involve the use of solutions containing oxidising agents. These agents are mainly chromates or nitrates and the corresponding acids. In many other cases, however, the use of peroxygen compounds is indicated. The treatment of metal surfaces with oxidising agents is first of all used where an oxide film on the metal surface proper is to be produced. In another application the treatment serves to remove undesirable surface impurities, or generally to remove surface layers of metal. In a somewhat different application, oxidising agents are used to keep the constituents of certain treating solutions in the proper state of oxidation. A typical oxide film producing process is that of browning, which is a simple and economical way to obtain a relatively rust-resistant finish on iron and steel. A highly durable black finish can also be produced on zinc and cadmium surfaces. This finish actually consists of a strongly adherent film of fine-grained copper oxide. The article to be treated is first dipped in a bath containing a soluble copper salt and potassium chlorate. The surface is subsequently treated with hydrogen peroxide solution. A process typical of the second category listed is a treatment for rust removal and pickling of iron, in which the exposed iron surface is left light and shiny. This is achieved by adding a peroxygen compound to the pickling acid. Finally, the properties of electrical contacts composed of tungsten carbide

"Airflo" TRADE MARK

- the new K.F. type DUST COLLECTING UNIT



Occupies minimum factory space. Costs little and is extremely efficient. Suitable for dealing with all grinding dusts as well as wood sawdust. Supplied wired from motor to starter. Filter unit is under suction. Dust inlet can be positioned on any of three sides.

- Capacity 800 c.f.m.
- 4" S.W.G.
- 2 h.p. Motor. 2800 r.p.m. 400/440 50 ~ 3 phase.
- MEM STARTET push button.
- Size 2' × 2' × 4' 8" high.
- Isolating Switch.
- Hand Shaking Device.

INDUSTRIAL FAN & HEATER CO LTD
"Airflo" WORKS, BIRMINGHAM 11
Phone: VICtoria 2277

MANCHESTER: City Bldgs., 69 Corporation St., 4
Phone: Blackfriars 6918

WE SHAPE THE THINGS TO COME

We are proud to have been entrusted for many years with prototype, research and experimental work from Britain's leading aircraft and automobile manufacturers. We employ none but the finest craftsmen and are recognised as being amongst the foremost specialists in sheet metal manipulation in the country.

Experts in high class shape panel work, aircraft fabrications and assemblies.

A.I.D. & A.R.B. APPROVED

ABBEY

PANEL & SHEET METAL CO. LTD.

OLD CHURCH ROAD,
LITTLE HEATH,
COVENTRY
Tel.: COV 88217

and copper can be improved by etching their surface with a solution containing about 15 to 30 per cent of hydrogen peroxide and about 8 per cent of ammonium hydroxide. But these processes, of course, are only a few among many employing oxidising agents.

● *NEW COPPER ALLOY*

It is reported that a search made for a copper base alloy of high stress-corrosion resistance has led to exceedingly interesting results. In the course of this work, the copper-nickel-silicon alloy series was studied and particular attention was paid to the effect of the nickel-silicon ratio upon the properties of the alloy. It was discovered that within narrow ranges of nickel and silicon a copper-nickel-silicon type alloy could be rendered non-susceptible to stress-corrosion failure by the addition to the alloy of a critical amount of iron. The susceptibility of an alloy to stress-corrosion cracking is believed to be due to the existence of continuous anodic zones within the alloy structure. When the alloy is subjected to a corrosive medium, fissures start at the metal surface as the result of electro-chemical action between the anodic and cathodic areas. If high tensile stresses arising from tensile or torque loading are present at the surface, the small fissures increase the magnitude of local stresses at the apex of the fissures, and this increases their depth. New metal is exposed which is consumed by electrolytic corrosion. Consequently, the stresses are further increased at the fissures and the material ultimately fails. A critical minimum requirement of iron, it is believed, results in the elimination of the contiguous zones of different electro-chemical potential. While the optimum properties may be attained in either the cast or wrought form, some variation of the iron percentage is desirable because of its influence upon the hot and cold working properties. Within a composition range of 3·5 to 5 per cent nickel, 0·7 to 2 per cent silicon, and 0·3 to 1 per cent iron, with the balance essentially copper, the alloy may be cast to form satisfactory articles. For the production of wrought products, silicon should be limited to 1 per cent and iron to 0·5 per cent.

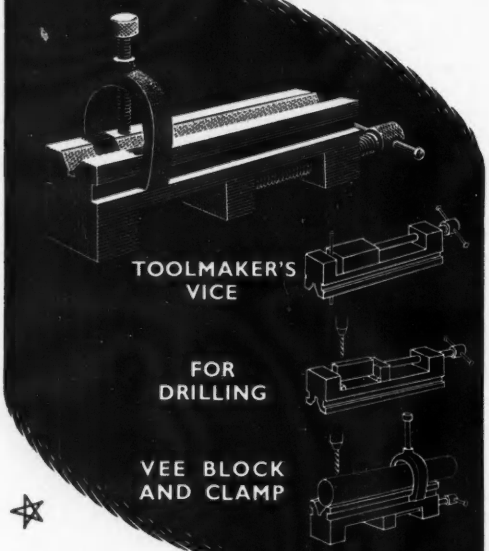
● *AIR-BORNE BEARING FOR GAS TURBINES*

In floating bearings of the air-borne type, the air or other fluid must be supplied under a certain pressure which requires the provision of a source of compressed air supply. In certain designs the bearing is fed with compressed air by means of a compressor arranged upon or actuated by the very shaft journalled in the bearing concerned. In the case of air-borne bearings, the possibility of failure of the compressed air supply cannot, of course, be ruled out altogether, and safety devices must therefore be incorporated in such installations to cope with such an emergency. A particularly interesting design of such a compressed air-borne bearing has now been developed for application to gas turbines, and provided its operating characteristics come up to expectations, the gas turbine field should indeed provide many interesting applications for this bearing type. As the inventor of the new bearing points out, by supplementing the mechanical bearing by a compressed air bearing which either surrounds it or is surrounded by it, the gas turbine rotor can be permitted to turn at a much higher speed and without any risk from a failure of the air bearing, and without imparing the starting and stopping characteristics of the turbine. When starting, the shaft rotates in the mechanical bearings, but as soon as the output of the shaft-driven compressor has reached a sufficient pressure, the air bearings become automatically operative, while the mechanical bearings are made practically inoperative. In the case of an unexpected failure of the air bearings, the shaft will be fully supported by the mechanical bearings, which should absolutely preclude any risk of a breakdown.

● *ELECTROSTATIC SAFETY DEVICE*

There exist a large number of ingenious methods for using electrical and optical phenomena for the operation of safety devices, burglar alarms, and the like. In fact, both the number of possible applications of such devices and the number of practical solutions are so large as to appear to be almost inexhaustible. A somewhat unusual arrangement which utilises the distortion of an electrical field to safeguard power press operators may be of more than ordinary interest insofar as this system seems to be free from certain limitations inherent in photoelectric devices. In its original form the electrostatic capacitance field device can be used on any type of machinery that is equipped with clutch and brake devices which permit the machine to be stopped when a signal is given. This class of machines includes punch presses, rubber mills, die casting machines, and shears, etc. When installing the safety device, e.g., with a press, the electrostatic capacitance field is tuned and adjusted to the normal earth potential of the press, its dies, and the work. When the electrostatic field is unbalanced by an operator's hand or other undesired objects entering the area of the protective field, relays within the control unit go into action and actuate press and brake solenoids which stop the press. The machine cannot then be restarted until the unbalance is removed. The loops producing the electrostatic field have to be designed to suit existing conditions. The protective field radiated by the loops can be extended or reduced in area as required. The unit can be made to function continually or only during certain phases of the working cycle.

A single tool with a multitude of uses!



Here is a toolmakers' vice which, merely by reversing, becomes a vee block complete with sliding clamp. The vice has a capacity of 3" and two interchangeable sliding jaws, the larger of which houses two parallels for supporting work to be drilled. A $\frac{5}{16}$" hole at the end of the tool enables small work to protrude below the bed. In finish and precision, the vee vice is a practical man's tool—an ECLIPSE tool in fact. Ask your dealer to show it to you.

Eclipse COMPOSITE VEE VICE

OBTAINABLE FROM YOUR TOOL DEALER

Made by James Neill & Company (Sheffield) Ltd.

EG119

CH29

Accurate over ENTIRE Hardness range

The use of the 136° Pyramidal Shape Diamond Indenter on the Vickers Hardness Tester ensures the maximum stability when being used with the hardest of materials, and thereby overcomes the indenter deformation associated with the "Steel Ball" Indenter: — V.P.N. (Vickers Pyramid Numerals) are recognised by Metallurgists throughout the World as being the highest standard of accuracy.

Write for full details to: Vickers-Armstrongs Ltd., 13 City Road, London, E.C.1., or Cooke, Troughton & Simms Ltd., 15/17 Broadway, London, S.W.1., or Wild Barfield Electric Furnaces Ltd., Elecfurn Works, Watford By-Pass, Herts.

VICKERS-ARMSTRONGS LTD

13 CITY ROAD · LONDON · EC1

'PHONE: METROPOLITAN 8877 · 'GRAMS: VICKSBOX, AVE, LONDON

● *CONSTANT VOLUME COMBUSTION*

In a recent paper it is shown that by combining the results of an elementary thermodynamic analysis of the temperature distribution in the burned gases of a constant-volume bomb with an examination of the velocity relations at the flame front, it is possible to relate the normal burning velocity to the time rate of production of burned gases. Integration of this equation then yields an estimate of the time required for the combustion process. In the elementary discussion of constant-volume combustion of gaseous mixtures, it is assumed that the products of combustion reach a uniform temperature. Actually, during the course of burning, and at the instant combustion is concluded, a temperature gradient exists in the burned portion of the gases. Consequently, the final temperature is not reached until the temperature gradient has dissipated itself through heat conduction. Since the flame front moves through the unburned gas at a finite velocity, the charge located between the ignition electrodes burns before the charge located at the walls of the bomb. If the unburned gas is subdivided into infinitesimal layers, and it is assumed that the burning process proceeds from layer to layer, it may be assumed that each layer burns at essentially constant pressure. Thus, constant-volume combustion is found to be a series of constant-pressure combustions. In analysing the combustion process, it is assumed that no heat transfer takes place in the burned or unburned gas. Naturally, the hot burned gases occupy a greater volume for a given mass, and it can be shown in a specific case that when 50 per cent of the gas is burned, it occupies 77 per cent of the total volume, thus placing the unburned gas under compression.

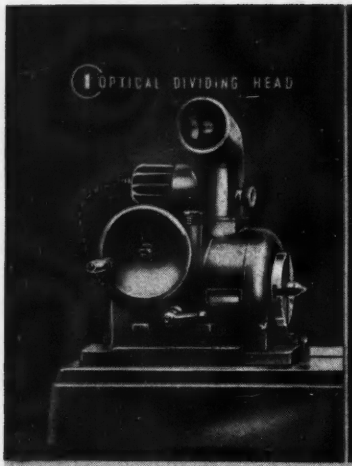
● *GLASS AND QUARTZ PAPER*

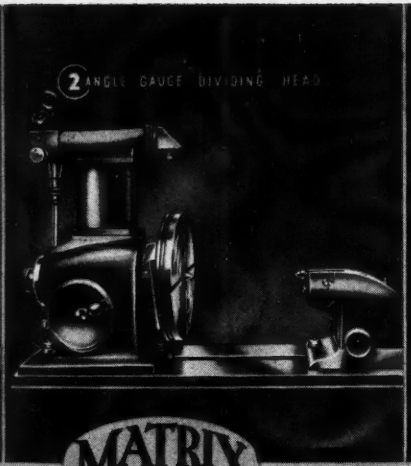
Important advances in the production of fine glass fibre have made possible the production of an all-glass paper which is already finding wide commercial application as an air or liquid filter medium, as an electrical insulating material, and as a reinforcement in the laminating field. Manufacture of the new product was made possible by the development of a technique to produce glass fibres of hitherto unheard-of fineness, the thinnest fibres being 0·05 micron in diameter. This achievement was followed up shortly afterwards by the production of quartz micro-fibre as fine as 0·5 micron. Such fibres of both glass and quartz can be dispersed in water, much the same as organic fibres, collected on a screen and converted into a thin paper sheet, as thin as 1½ to 3 mils. It is claimed that, for the first time, the durability of glass and its dimensional stability as well as its non-hygroscopic properties and high dielectric strength have become available in thin paper sheets by processing these fibres through standard paper-making equipment. As regards the quartz paper, this material has inherent electrical insulating properties which make it suitable for very specific electrical insulating purposes. This "paper" withstands temperatures of 3000° F, has low losses at high frequencies, and shows practically no deterioration when exposed to radiation. It should prove highly suitable in connection with equipment for nuclear reactors and related equipment. Quartz paper is boron-free and neutrons will pass through it; this paper should therefore be suitable as insulating material for cables or other equipment used in the neighbourhood of nuclear reactors, as it would not be rendered radioactive by neutrons passing through it.

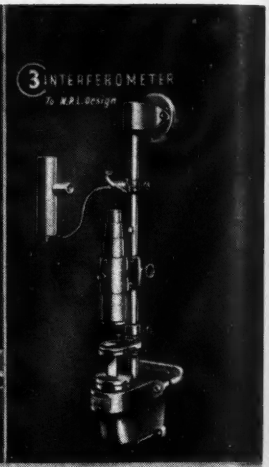
● *ENAMEL FOR GAS TURBINE BLADES*

During the last war, work was started on the use of enamels for providing protective coatings on exhaust manifolds for aircraft engines. The object was, of course, to make use of cheaper materials in place of the scarce metal alloys previously used for such exhaust systems. The enamel coating prevents the hot exhaust gases from oxidising, corroding, and carbonising the base metal. The results of these tests were satisfactory, and very considerable progress in providing enamels for a variety of similar purposes has been made in recent years. Enamels are known to have high erosion resistance and an investigation was recently made into the possibility of utilising this erosion resistance for the purpose of reducing blade wear in gas turbines of the pulverised coal fired type. As no basic information was found to be available with regard to the abrasion resistance of enamels to particles suspended in high temperature flames, special equipment was built to create conditions which would simulate those obtaining in pulverised gas turbine practice. The test enamel samples were placed at a distance of three inches from the aperture of a torch nozzle which impinged a flame at 1475° F upon the sample with a flame velocity of some 650 fps. Both abrasion under perpendicular and tangential impact were studied. In one series of tests the particles carried by the gas stream were alumina particles of 74 to 105 microns size, while in other tests coke breeze particles of 177 to 250 microns size were used. In commenting upon the actual test data, the report states that the velocities of the flame and the particles did not seem to be fast enough to cause noticeable abrasion of the enamel at the test temperature.

For further information on developments reviewed in THE BLUE PAGES, readers are invited to write to the Editor.







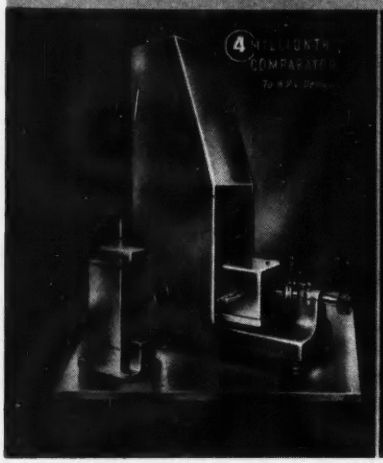
MATRIX
COVENTRY GAUGE & TOOL COMPANY LTD.

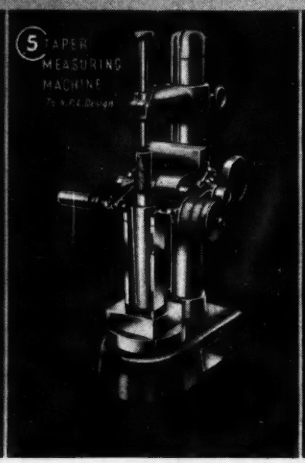
Measuring Instruments

TO A DEGREE OF EXCEPTIONAL ACCURACY

These specialised instruments essential for the control of accuracy to the finest limits, have been produced by Coventry Gauge in full collaboration with the National Physical Laboratory. The name "Matrix" is an assurance that no finer quality may be obtained wherever the highest degree of accuracy is required.

Coventry Gauge
& TOOL CO. LTD.
COVENTRY, GT. BRITAIN





Copyright

THE ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

VOL. XIV. No. 2. FEBRUARY, 1953

EDITORIAL

DISCUSSIONS we have conducted with a fairly representative cross-section of visitors to the Packaging Exhibition held recently at Olympia, indicate that their interests could be subdivided into three main groups.

Dealing with these groups in succession, the first one concentrates on packaging as a sales medium. The package is regarded as so much display advertising space. Although the middleman must have been convinced of the merits of the contents of the package before placing orders for the product, it is argued that the package makes an essential contribution towards effecting the final sale of the product.

The second group is more concerned with the functional aspect of packaging. It aims at preserving the product in transit, and ensuring its safe delivery; the results of the manufacturer's productive efforts should not be allowed to deteriorate, however slightly, and thus defeat the ultimate object of supplying the product in conformity with accepted standards.

Although the objectives of the second group are certainly in the right direction, they seem either to ignore or to pay insufficient attention to the economic factors involved.

This leads us to the third group consisting mainly of people who, basically, are trained engineers and specialise in packaging technology. Their way of looking at this subject is to regard modern packaging technique as a continuation of the flow of material through the plant, beyond the inspection point to the packaging point, to temporary storage, and finally to loading for consignment to customers. Viewed from this angle, packaging becomes a material handling problem, or, in other words, it represents an extension of the manufacturing cycle from the final product stage onwards. This further handling must be carried out with the same efficiency that characterises modern production methods. This means that, as handling in the production process becomes increasingly mechanised, so must packaging.

It has been variously estimated that of the main items that make up the total cost of the product, nearly a quarter is attributable to material handling. If handling costs due to packaging could be reduced, and although no figures seem to be available it is suggested they could be, the rather unfavourable percentage of handling cost to total cost of the product could be improved. More and better packaging machines are needed; they not only lighten the job, they also speed it up.

The cost of these machines must be such that, when amortisation has been taken into account, the reduction in production costs is a very real one. It must be borne in mind that packaging, in a direct sense, does not add to the value of the product, though it adds to its cost. Quite apart from reducing production costs and thus helping the export drive for British products, efficient packaging machines are one of the best export articles in themselves.

Fortunately, there are signs that such machines are being built, and for those who have been watching the often slow and painstaking developments over the last few years, the future must seem bright.

Here and there one meets a machine, first seen some years ago, with a new and better feeding device, or one that was hand-fed, equipped with an automatic feeder. Step by step, co-operation between users and designers carries mechanisation further towards automaticity. This field of special machine design has a number of lessons to offer to designers of many other machines relying on automatic feeds, intermittent gearing, counting, weighing, sorting and a vast number of other problems of a similar nature.

Packaging materials are also of vital importance, perhaps no less than the packaging machines themselves. The co-operative effort of firms in this industry has proved to be of the greatest value in research on and testing of new materials. Of the many new materials and their applications we shall only mention that a water-repellent fibre board that withstands extended soaking can now be produced economically and is already applied to packing food products for the Armed Forces.

Owing to lack of space, only two new applications can be mentioned in order to indicate the trend of development. These are: a pre-coated thermoplastic adhesive which bonds to glass or metal and is used with a special labelling machine, and a P.V.C. type heat-sealed bag used as a drum liner for corrosive liquids. The bag is made of two foils which, by application of heat and

(*Concluded on page 67*)

Wind-Tunnel Measurements on Motor-Cycle Models

DETERMINING STREAMLINE FAIRINGS FOR RACING MOTORS

By N. SCHOLZ. (From *VDI-Zeitschrift*, Vol. 95, No. 1, January 1, 1953, pp. 17-20, 15 illustrations.)

THE 279 km/hr (174 mph) speed record for motor-cycles remained unchallenged from 1938 until April 1951, when a NSU motor cycle* (500 cm³, supercharged engine developing 110 hp) passed the test-kilometer in 11·7 secs, i.e., at a speed of 290 km/hr (181 mph). The motor-cycle, Fig. 1, was provided with a streamlined body fairing which was developed in comprehensive wind-tunnel tests. In October of the same year,

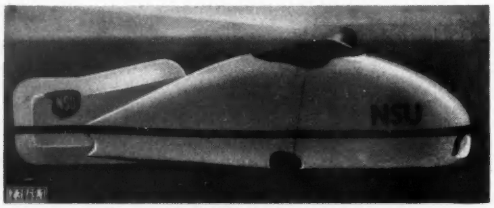


Fig. 1. **The NSU single record machine.**

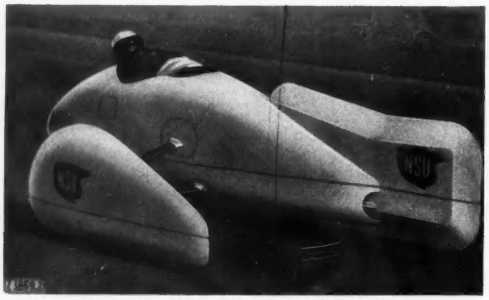


Fig. 2. **The NSU sidecar record machine.**

a similar NSU motor-cycle, shown in Fig. 2, achieved the absolute speed-record for sidecar combinations (248 km/hr, i.e., 155 mph).

FORCES ACTING ON THE VEHICLE AND THEIR MEASUREMENT.

The power requirements of motor vehicles at higher speeds on a level course are mainly determined by the drag of the vehicle.†

Apart from air resistance in the direction of travel, there is lift in the vertical plane which can lead to considerable changes in wheel loading on the road and thereby alter the manoeuvrability of the vehicle. Furthermore, lateral forces due to yaw may tend to turn the vehicle from its course. These conditions are of special significance in the case of the motor-cycle as there are only two wheels transmitting the frictional forces existing between road and wheels. Moreover, the vehicle has an additional degree of freedom, namely, rotation about its longitudinal axis.

Wind-tunnel tests have reached a high degree of perfection in aviation. It is only recently that their successes could be emulated in the field of motor vehicle design[1,2].

The wind-tunnel used in the tests described has a circular throat of 1300 mm diameter, capable of generating air speeds up to 234 km/hr (146 mph) and employing

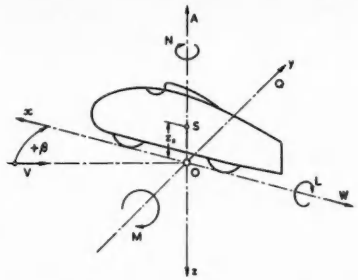


Fig. 3. **Nomenclature and co-ordinate system for six-component measurements.**

x, y, z = Longitudinal, lateral and vertical axes ;
W, Q, A = drag, lateral force and lift ;
L, M, N = rolling moment, pitching moment and yawing (or turning) moment ;
O = origin of co-ordinate system ;
S = centre of gravity ;
z_s = distance O-S ;
V = air speed ; and
β = angle of yaw.

six-component scales for measuring the aerodynamic forces. These scales have been described elsewhere[3]). The model was suspended in such a way that it could be turned about a vertical axis so as to enable measurements to be made at wind directions of various degrees of yaw. The system of co-ordinates to which the

Fig. 4. **Model of the NSU RK II machine.**

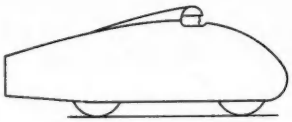


Fig. 5. **Streamline model K without stabilising fin.**

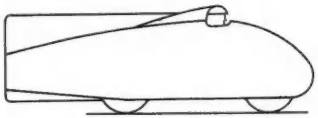


Fig. 6. **Streamline model K_2 with high, straight stabilising fin.**

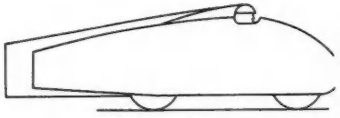


Fig. 7. **Streamline model K_2 with overhung slanting stabilising fin.**

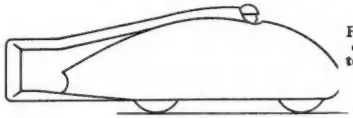


Fig. 8. **Model X, corresponding to the record machine.**

Figs. 4-8. Model shapes tested.

*Made by Neckarsulmer-Fahrzeugwerke, A.G.

†See "Present-Day Car Design Trends—Aerodynamic Streamlining Versus Styling," "The Engineers' Digest," Vol. 11, Nos. 8 and 9, 1950,—Ed. E.D.

measurements of six components (three forces and three moments) are referred to shown in Fig. 3. For simulating the ground effect, a stationary flat plate was used, which, however, did not touch the model.

THE INFLUENCE OF STREAMLINING.

The characteristics and behaviour of the NSU motor-cycle "RK II" at high speeds were known. Knowledge of the influence of streamlined fairings on these characteristics was completely lacking. Therefore, 30 differently streamlined models were tested in the wind-tunnel in addition to the model of the original non-streamlined machine (Fig. 4). Some of the models tested are shown in Figs. 5 to 8; their scale was $^1/_5$ full-size.

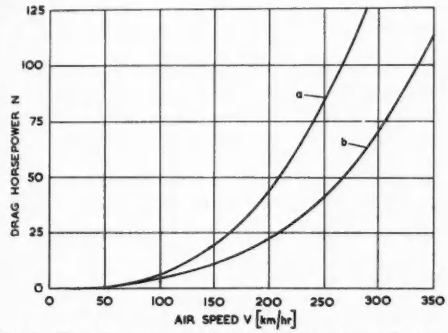


Fig. 9. **Drag horsepower plotted against air speed at angle of yaw $\beta = 0$ deg.**
(a) Non-streamlined model according to Fig. 4.
(b) Fully streamlined model according to Fig. 5.

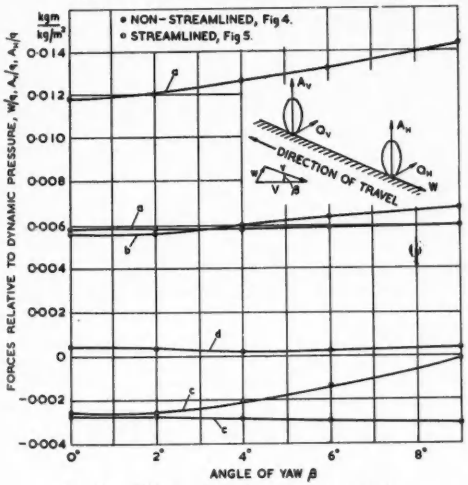

• NON-STREAMLINED, Fig 4.
• STREAMLINED, Fig 5.
FORCES RELATIVE TO DYNAMIC PRESSURE, W/q, A_V/q, A_H/q
ANGLE OF YAW β
DIRECTION OF TRAVEL

Fig. 10. **Lift and drag forces on the wheels.**
(a) Drag W/q.
(b) Lift at front wheel A_V/q.
(c) Lift at rear wheel A_H/q.

The main purpose of streamlining is to avoid the break-away of the airstream from the vehicle. This can be achieved by gradual changes in body cross-section, tapering away towards the tail. The minimum cross-sectional area of the body is determined by the space requirements of the machine and rider, and can be considered as being constant. With this cross-section, and within a certain range of body slenderness ratios, the drag remains almost constant. Drag increases approximately as the square of speed; consequently, drag horsepower increases as the third power

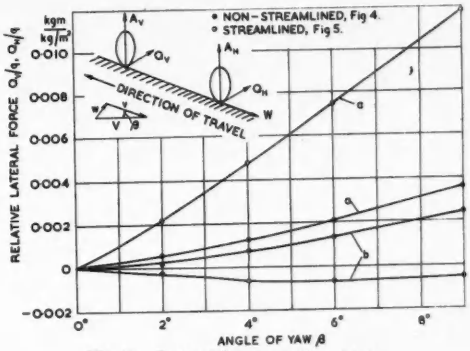


Fig. 11. **Lateral forces on the wheels.**
(a) Lateral force at front wheel Q_V/q.
(b) Lateral force at rear wheel Q_H/q.

of speed. This is plotted in Fig. 9, which shows, within the applicable speed range, a reduction of drag horsepower by streamlining to about half of its original value. As other vehicle losses (gearing, wheels) increase linearly with speed, the power required to overcome drag predominates at high speeds. Fig. 10 shows the lift and drag forces acting on the front and rear wheel of the model streamlined according to Fig. 5, as compared to those of the non-streamlined model shown in Fig. 4. For symmetrical flow ($\beta = 0$ deg.) both models have lift on the front wheel, but down load on the rear wheel; the curves show clearly how these values change with increasing angle of yaw.

Owing to differences in the pressure distribution around the fairing there are also horizontal, lateral forces, which are strongly dependent on yaw (Fig. 11). These forces must be resisted by the adhesion of the wheels to the track. The turning moment (yaw) N (Fig. 3) about the vertical axis determines the directional stability of the vehicle. The streamlined model, although quite satisfactory at zero angle of yaw, shows great directional instability with increasing angle of yaw.

STABILISING THE VEHICLE.

In principle, the streamlined model can be stabilised by adding to the great lateral force acting on the front wheel a counter-balancing force on the rear wheel. This force is provided by a stabiliser surface (fin) at the tail. A measure for the directional stability is afforded by the position of the resultant aerodynamic

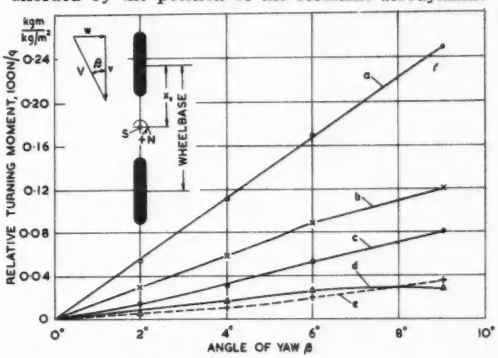


Fig. 12. **Turning moment N about vertical axis through the centre of gravity plotted against angle of yaw.**
(a) Model K according to Fig. 5.
(b) Model K_3 ,, ,, Fig. 7.
(c) Model X ,, ,, Fig. 8.
(d) Model RK II ,, ,, Fig. 4.
(e) Model K_2 ,, ,, Fig. 6.

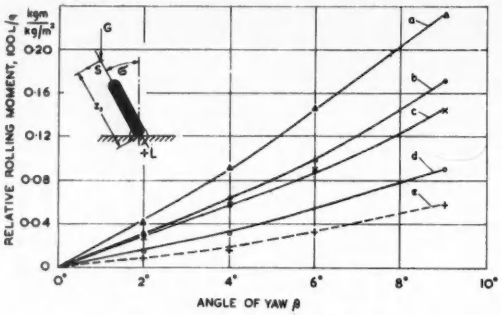


Fig. 13. **Rolling moment L about the track line plotted against angle of yaw.**

(a) Model K_2 according to Fig. 6.
(b) Model X " " Fig. 8.
(c) Model K_3 " " Fig. 7.
(d) Model K " " Fig. 5.
(e) Model RK II " " Fig. 4.

force relative to the turning point of the vehicle. If the aerodynamic force acts behind the turning point it has a stabilising effect. The stability criterion is therefore: $\partial N/\partial\beta < 0$. If $\partial N/\partial\beta > 0$ the vehicle is unstable, i.e., the aerodynamic force tends to turn the vehicle out of its direction of travel. Although not strictly true, the centre of gravity S can be considered as the turning point.

Fig. 12 shows a comparison between the turning moment curve of the non-streamlined model and the curves of the four models according to Figs. 5 to 8.

The rolling moment of the vehicle about the longitudinal axis is also of interest. This must be compensated by tilting the vehicle by an angle σ, as shown in Fig. 13.

The author suggests that the speed records achieved have fully justified the wind-tunnel tests and that such tests are essential for the successful development of high-speed machines.

BIBLIOGRAPHY

(1) SAWATZKI and W. WEISS: Die Übertragbarkeit von Kraftfahrzeug-Modellversuchen im Windkanal auf die Grossausführung. (The applicability of scale model wind-tunnel test results to full-scale motor vehicles.) *ATZ*, Vol. 44 (1941), pp. 581-586.
(2) KOENIG-FACHSENFELD, R.: Die Aerodynamik des Kraftfahrzeugen. (Motor vehicle aerodynamics.) Vol. 1 and 2, Frankfurt/M., 1951.
(3) MÖLLER, E.: Windkanalmessungen an Kraftfahrzeugen bei Seitenwind. (Wind-tunnel tests on motor vehicles with non-symmetrical flow.) *ATZ*, Vol. 53 (1951), pp. 74-78.

U.S.A.

The Use of Castings in Airframe Design

By A. H. PETERSEN. (From *Metal Progress*, Vol. 62, No. 5, November 1952, pp. 67-72, 6 illustrations.)

AEROPLANES are getting heavier because of a considerable advance in performance during the past few years. Aeroplanes flying at high Mach numbers are subjected to peculiar aero-elastic loads which make the proper distribution of mass in their structure of vital importance. Materials having high strength-weight ratios are more and more widely employed in airframe structures; furthermore, the size of the various individual components is increasing.

Casting processes, like all others used in the airframe industry, have their particular scope and place; the casting's place lies in the field of intricate configuration where it is advantageous to combine several units into one, or where highly cyclic loading can be avoided and where their strength is such that undue weight penalties will not be incurred.

It has often been stated that forgings, plate, sheet and other wrought products begin life as cast ingots and that the quality of the wrought product is dependent on the quality of the ingot. This is true; however, the simple statement requires qualification. No amount of subsequent extruding, kneading, upsetting, blocking, forging or rolling will remove all the defects found in an unsound ingot. Thus, the so-called "unhealed porosity" in aluminium alloy forgings can be traced to stringers or oxide inclusions occurring in the ingot. But to say that such a situation is the rule is unjust and takes credit away from the men constantly seeking to improve present-day techniques. We have yet to see the like of the typical forging or extruded structure in any cast aluminium product selected at random from typical production runs of today.

Consequently, the reference to the cast ingot as the origin of wrought products should be restated in some such words as these: starting with a sound ingot (which must be the premise), subsequent working improves properties to a degree not attainable by the simple process of pouring hot metal in a mould, regardless of the controls employed.

An aluminium alloy with 4·5 per cent copper-containing additions will possess, in the wrought and heat treated state, a hardness of over 110 Brinell and a tensile strength of 60,000 psi, but the same alloy, as cast, after hardening by heat treatment, will not develop much over 60 per cent of this strength.

Table I gives the strength values for various wrought and cast alloys in Specification AN-C-5 of the Departments of the Navy, Air Force and Commerce and now employed in the airframe industry. Included is 78 S, the newest wrought alloy being tested today, but for which allowable design stresses are not yet established. The spread between tensile strength and yield strength of the wrought materials as compared with the cast materials in this table strikingly illustrates a point.

ACCEPTANCE TESTS FOR CASTINGS

The aircraft industry probably makes static tests on more castings than on any other components of airframes, destroying three castings of the first production lot of each critical casting for an Air Force plane. In addition, standard test bars are pulled for each production lot of castings to determine if the lot meets specification values (which are founded on experience and on countless tests).

Some engineers take issue with the test-bar method of evaluating the strength of production lots of castings. If very careful attention is not paid to risering and chilling, they have a point, since a section out of a $\frac{1}{4}$-in. web may very well give a better value in tension than a $\frac{1}{2}$-in. test bar.

Aircraft castings are subjected to rigid radiographic tests and examination by fluorescent or magnetic penetrant to detect flaws. Rejections in the product of one foundry which I am acquainted with are running less than 5 per cent monthly.

A number of airframe companies have established radiographic standards showing acceptable and unacceptable internal defects. Similar standards have recently been published by the Bureau of Aeronautics. Such standards have been used for many years and have served to establish a common ground of understanding, thus reducing casting rejections, and assisting

foundries through a uniform interpretation. In greater or lesser degree, the defects shown on X-ray negatives are fairly common in castings produced in static sand and permanent moulds. Porosity, micro-shrinkage, gas holes and the like can be controlled. Whether they can be eliminated entirely is yet to be proved.

TABLE I. MINIMUM TENSILE PROPERTIES OF AIRCRAFT MATERIALS (Specification AN-C-5)

Material	Ultimate	Yield	Elongation in 2 in.
Wrought Aluminium Alloys (Bare)			
24 S-T 4	62,000	40,000	8%
75 S-T 6	77,000	66,000	8%
78 S	84,000	73,000	8%
Aluminium Sand Casting Alloys			
195-T 6	32,000	20,000	3%
356-T 6	30,000	20,000	3%
220-T 4	42,000	22,000	12%
Magnesium Sand Casting Alloys			
AZ 63-T6	34,000	16,000	3%
AZ 91 A-T 6	34,000	16,000	3%
Alloy Steel, Wrought and Heat Treated			
4340	260,000	240,000	10%
8630	125,000	100,000	17%
8740	180,000	165,000	12%

Recently it has been proposed that the continual static testing of castings be eliminated and replaced by the controlled analysis of casting defects on a statistical basis.

In addition to this common-sense approach to control, it is now general practice to indicate on drawings the critical areas of the part, the direction of loading, and otherwise direct the foundryman's and inspector's attention to the important considerations.

REQUIREMENTS FOR USE IN AIRFRAMES

A number of airframe factories normally employ factors of 1·25 or 1·33 in stressing aluminium and magnesium alloy castings. That is to say, if the part is a casting, the designer increases the loads by one quarter or one third, and this factor, incidentally, is one reason castings often fail to compete by weight with sheet metal assemblies. This factor has steadily decreased over the past few years, due to the constant efforts of engineers and foundrymen to improve design and technique. Today, many stress engineers contend that complex castings need no factor but should be treated like any other type of indeterminate structure, and statically and dynamically tested only as far as is necessary to determine performance under load.

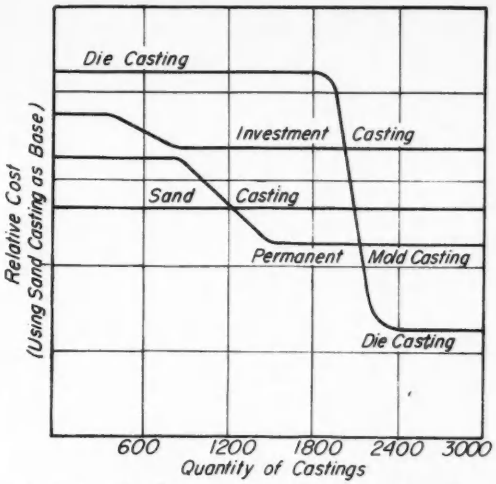


Fig. 1. **Relation between cost and quantity of castings, machined ready for use, indicating the approximate break-even point for four important casting methods—sand, investment, die casting and permanent mould.**

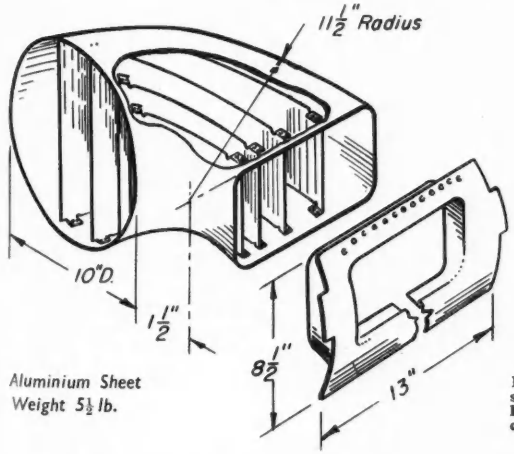
As strength requirements increase, however, the casting finds it more and more difficult to compete with the wrought alloys. This is strikingly true of steel alloys and consequently they are not widely used in the cast form in airframes today.

Where ductility or ability to take deflection is of prime importance, the casting takes a beating. After heat treatment, it is a rigid and unyielding member. Tied to sheet metal structures which work close to their yield stress, the casting's inability to "work" or deflect may cause early failure.

There is, however, a considerable number of castings of all types, configuration and size, of various aluminium and magnesium alloys, employed in structures of primary and secondary importance and for pressure vessels, valves and fittings, and wherever else they can be used economically and to save weight. This is shown in Table II.

MOULDING METHODS

The majority of the castings now used in aeroplanes are cast in sand moulds because quantities do not generally justify the cost of permanent moulds or other



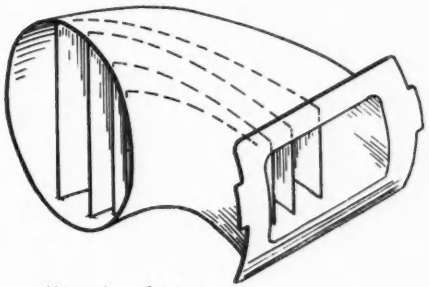


Fig. 2. **Alternative designs for cooling duct for cabin supercharger. Weight of sheet aluminium part at left is 5·5 lb, of magnesium casting at right is 7·5 lb. Despite the simpler design of the magnesium casting, this duct cannot be cast in production because of unsolved shrinkage problems.**

specialised processes. These are normally used when considerable machining can be eliminated or for pressure vessels. Die castings are attractive where dimensional accuracy is more important than structural properties. Figure 1 illustrates the point that the number of castings required to a given design has a considerable bearing on the moulding process.

Much publicity has recently been given to the "advanced" casting processes and techniques which may provide greater dimensional accuracy and soundness, yet it is the present writer's belief that sand castings are being produced today which are every bit as accurate and sound as required by the airframe application. As-cast mating and attaching faces are employed wherever the elimination of machining costs justifies the added expense of obtaining such smooth surfaces. Precision metal patterns are used for aircraft castings as a general rule.

TABLE II. AVERAGE QUANTITY OF CASTINGS OF ALL TYPES IN AIRCRAFT

	1949	1950	1951
Transport	525 lb	514 lb	479 lb
Bomber	702	658	637
Fighter	154	184	198
Trainer	—	164	177

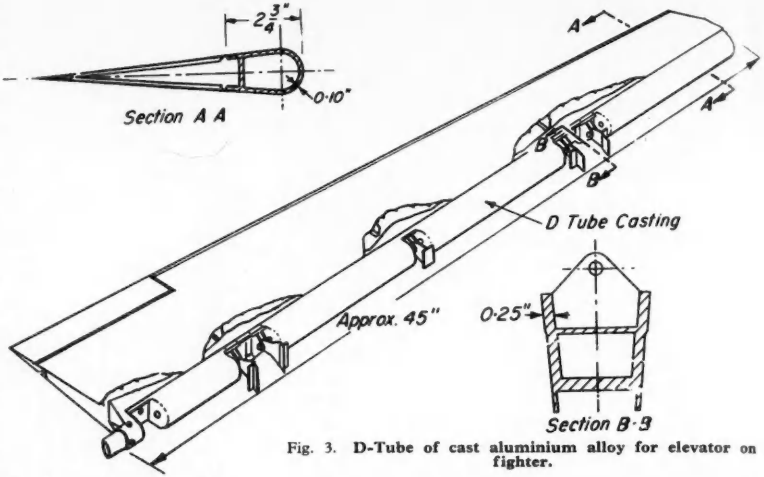


Fig. 3. **D-Tube of cast aluminium alloy for elevator on fighter.**

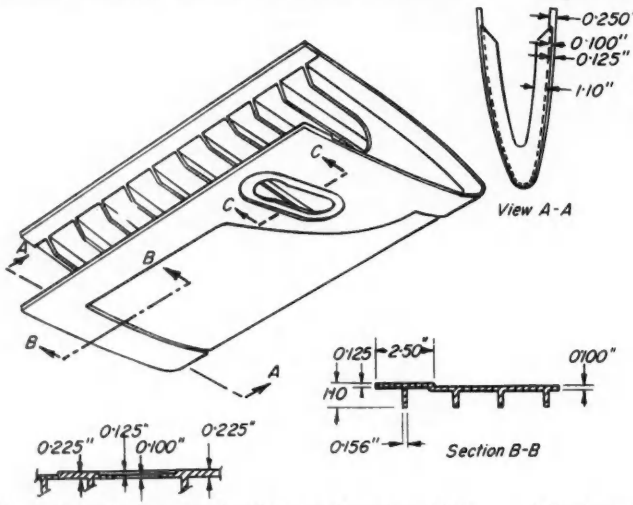


Fig. 4. **Wing leading edge for fighter. Magnesium AZ 91 sand casting, not heat treated. The finished weight is 7·4 lb—about equivalent to a sheet metal component.**

Paying $4000 to $10,000 for precision patterns for typical components weighing in the order of 6 to 20 lb or for specialised metal or ceramic moulds, or for the use of specialised equipment for controlling pressure and temperature in the mould, must certainly be justified on a sound economical basis. Yet the industry is continually paying such costs—often merely for the advancement of the art.

The writer has been privileged to study many of the latest advanced casting processes and techniques, the Croning or shell moulding process, the Parlanti, the Wessel, the Mercast, the Bacco, the Osbrink, the Permafuge and others. Each of these constitutes a step forward; each has decided limitations of source, cost or size, or has not advanced to become generally accepted as a production process.

SOME CURRENT PROBLEMS IN SUBSTITUTION

Aircraft designers are intensely aware of the advantages of casting large, intricate and accurate components as a single part, within the inherent limitations which set castings apart from hot and cold worked metals. Castings will continue to be employed as widely as these limitations permit. Improvements in casting techniques will continue to refine structures, reduce porosity and micro-shrinkage, and may some day increase the physical properties of standardised alloys. Far from ignoring the foundry, it has been through the demands of the aircraft engineer, the time he has spent in research, the controls set up due to his demands, and the willingness of foundries serving the industry that marked advancements are being made. The following illustrations will attest to this fact and point the reasons for continued effort.

Figure 2 compares ducts made of sheet metal and of a single casting. This duct cannot be cast in production because of unsolved problems, yet it should be noted that it weighs 2 lb more than its sheet metal counterpart. It is no cheaper to produce, despite the elimination of three dies and two welding fixtures, because of the difficult coring problems and the special techniques required to obtain uniform metal flow throughout the very thin structure. The 0·10 in. required for the casting is double the thickness of the 0·051-in. 3 S-O aluminium alloy sheet in the current design. This is a typical example of one very important reason why castings are not more generally employed in aircraft.

(*Concluded on page* 66)

Soviet Trends in Gas Turbine Development

By J. Mannin

In the following article some Russian views and designs in the gas turbine field outside aviation are surveyed. Soviet engineers have much faith in this development but can boast of only modest achievements, some details of which are described.

In a survey of Soviet gas turbine engineering, it is useful to recall certain facts which define the observer, his instrument, and the panorama to be seen.

The instrument throughout these articles is a competent analysis of published information. In the present context, the limited sources of information, in turn, restrict the range of this survey because an important part of gas turbine engineering is devoted to aircraft engines and thus falls into the clutches of military security. Indeed, the Russian blackout in this field is more severe than that of the Western Powers. For this reason, the aircraft gas turbine will not concern us here.

This chapter of our survey of Russian engineering differs from others in one important respect, namely, the position of the observer. In discussing mechanical technology in its various branches, the engineer of Western Europe relies on knowledge rooted in tradition. Even if the strength of his position makes his mind impenetrable as well as firm, at least the confidence acquired in 100 years of, say, lathe construction is real.

In gas turbines we are all young. This is not intended to belittle the great achievements of the last decade of gas turbine engineering, nor to deny their solidity and sound engineering foundation, but, though engineers often love to think of themselves as men who can achieve the impossible, this passion cannot alter the fact that engineering is the art of achieving that which is worthwhile. To achieve the impossible by prohibitive means is not engineering and in gas turbine development we have not yet reached (with the notable and vital exception of aircraft engines) a sound balance between effort and achievement. Nor, if we may put the conclusion ahead of the survey, have the Russians. In short, we compare some achievements of designers stimulated to a large extent by faith.

It is curious to note in parentheses that men working for what is logically a faith frequently seek rationalisations outside their field of competence to which they can fondly cling. Over here I have heard it said that rotary motion is a higher form of existence, an idea which philosophers will recognise as having been held by Aristotle and developed to a great refinement by Ptolemy. The corresponding piece of nonsense mentioned in a Soviet article is that the gas turbine represents a higher form of " dialectical development " because it reduces the relative magnitude of friction losses. This, I think, is both wrong and silly, but who will deny that wrong rationalisations often produce right actions?

Lastly, Russian progress in gas turbines is part of the panorama of power engineering. In view of the many misconceptions, it is perhaps advisable to add a few remarks on the Russian power industry. In this branch of industrial development the Soviet effort, measured by the standards of Western Europe, has consciously striven towards and achieved the highest achievement in any industrial field. The early insistence on electrification formulated in the famous slogan " Communism is Soviet power plus electrification of the whole country," the spectacular water power projects of the early thirties and many other projects have led to the present stage where Russian power output per head of the population is about 50 per cent of the British, whilst Soviet steel output is less than 30 per cent, and in some important branches of production the percentage is even lower.

From this it must be concluded that Russian gas turbine development operates against the background of rapid progress in all branches of power engineering, and of a well-established and thoroughly planned industry. Indeed, we find a general readiness to expect and admit novelty in power engineering, but also a recognition of aims and criteria as clear and consistent as any.

In studying Russian sources on the origins of power technology we are confronted with the customary comic turn of original inventors, invariably Russian, and only prevented from making use of their native genius by the foreign subservience of the Tsars. Thus, a certain I. I. Polzoonov must have been laughing his head off when twenty years later James Watt after a painful effort lasting ten years, repeated the invention of the steam engine. However, on the history of gas turbine development, Soviet literature is exceedingly modest. To preserve the natural order of things, a Russian inventor did in fact start the construction of a gas turbine in 1897. In this design he also embodied the radial turbine principle, which was then still unknown even in steam turbine practice. However, it is conceded that the work remained unfinished and, soon after the turn of the century, further progress took place in Germany and France.

In the thirties, theoretical research into gas turbines was taken up by Russian Research Institutes and it is now claimed that the supremacy of the constant-pressure cycle was recognised by Soviet workers long before the present stage of achievement had been reached and this cycle became practically universal. The boast that an original Russian text book on gas turbines was published in 1935 " before the appearance of industrial gas turbines " is another characteristic feature of the Soviet approach. Whilst some may thick it premature to write a text book on non-existing gas turbines, Russian experience seems to show that such an approach has been fruitful in a number of fields of endeavour.

Gas turbine technicians realise that there is hardly another field of design wherein extensive analysis, before choosing the parameters of a project, is equally vital. Whilst a gas turbine installation is inherently well suited to generate large powers in a small space, its efficiency is extremely vulnerable. This vulnerability applies to major design features as well as to certain points of detail design. Design analysis is concerned with major design parameters. It is not a mere truism to say that it is particularly easy to construct a very bad gas turbine installation.

In the simple gas turbine cycle, air is compressed by the input of mechanical work, heated by combustion at constant pressure and, finally, its energy is reconverted into mechanical work in the gas turbine proper. Compared with the gas turbine cycle, the steam power cycle can be said to rely on thermal compression. For this reason, the transformation between mechanical energy and thermodynamic energy operates only upon the energy output actually delivered in the form of power. Such a transformation is inevitably associated with losses. The replacement of thermal compression by mechanical compression in the gas turbine cycle imposes a double transformation which now operates upon a rate of exchange of energy four to five times the power delivered. Consequently, the efficiency of the cycle multiplies the margin of efficiency of transformation by a factor of 4-5. Below a certain standard of " transformation efficiency " a gas turbine installation is not merely poor but useless. Gas tur-

bine development cannot succeed without prior knowledge of the demands to be made on the quality of transformation in the compressor and the turbine. These and other demands depend on the actual thermodynamic cycle of the gas turbine installation. The cycle is characterised by the inlet temperature and the pressure ratio of the compressor, and by the final temperature to which the air is heated before entering the turbine.

The pressure ratio is the only variable which controls the efficiency of an ideal gas turbine cycle, without losses. In such a cycle, the higher the pressure ratio, the higher the efficiency, but also the higher the ratio between the total energy transformation and the power output of the installation. The two conflicting effects in a real cycle produce an optimum pressure ratio, the value of which depends on the other parameters of the cycle. This value can be predicted by analysis. In stationary installations it is customary to reach and even slightly exceed the optimum to obtain the highest power output from an installation of a given size. This practice is equally in evidence in Western and Russian developments.

The compressor inlet temperature plays a special role in aviation, which is outside the scope of the present survey. Insofar as it is the ambient temperature (the lower datum of the thermodynamic cycle) it cannot in principle be influenced. However, circumstances exist in Soviet territory where the benefits of a cold atmosphere can be utilised. A reduction of ambient temperature from 20° C to — 30° C increases the power of a gas turbine installation by about 55 per cent and its efficiency by 25 per cent. In special cases where peak loads occur in winter the temperature effect can turn a marginal disadvantage into a decisive advantage of a gas turbine installation.

The final temperature after combustion is by no means determined by the combustion process. A large amount of excess air must be mixed with the combustion products to reduce the temperature to a level which the materials of the turbine can withstand. The higher the combustion temperature the larger is the surplus power developed in the turbine over and above the power needed to drive the compressor, and the smaller is the effect of transformation losses. A new branch of metallurgy has arisen to develop materials which permit ever-increasing turbine inlet temperatures. Considerable advances have been achieved in aircraft gas turbines in which a relatively short life is acceptable. In other gas turbines, the economics of which demand lives of the order of 100,000 hours of operation, progress has been very gradual.

We can summarise this aspect of gas turbine engineering by saying that no industrial country can embark upon original gas turbine development without first attaining the skill in producing units of energy transformation above a certain level of excellence and without possessing the metallurgical resources for the manufacture of creep-resistant turbine components able to withstand high temperatures. Improvements in energy transformation efficiency and in high-temperature creep strength are the chief avenues of progress from which the simple type as well as all other types of gas turbine installations can benefit. There is ample evidence to show that Soviet engineering is catching up with the average attainments of Western technology in both these fields, but has no outstanding successes in either. The trends of development are roughly along the same lines pursued in Western Europe and the U.S.A. In compressor design, no original rotary displacement compressors have appeared and designers favour the axial flow compressor with a moderate pressure ratio per stage (about 1·07). Rotor and stator blades of symmetrical profile are preferred. Clearly, Soviet technicians, like those in the West, have largely accepted the aerodynamically straightforward solution for high efficiency compression, in spite of its mechanical complexity and expense. In the design of turbine blading, Soviet engineers do not seem to have found " aerodynamic blading " of special merit and it is said that profiles employed in steam turbines are used. A turbine efficiency of 88 per cent and a compressor efficiency of 86 per cent are considered good for present-day practice. Values of 92 and 90 per cent respectively are stated to be possible in Soviet literature. No interest is shown in the centrifugal compressor for other than aircraft installations.

The temperatures thought possible with materials available today do not exceed 650° C, but in one experimental installation designed as a superimposed unit in a two-stage cycle, a temperature of 700° C is foreseen. These temperatures are achieved by the use of the same type of austenitic steel favoured elsewhere, having a chromium content of 13-16 per cent, a nickel content of 12-15 per cent, and small percentages of molybdenum, tungsten, titanium and columbium. Development is proceeding on chrome-nickel steels with a high cobalt content (up to 65 per cent) which will allow turbine inlet temperatures in excess of 700° C. The same type of alloy is used for the blading and the turbine discs.

Improvements of energy transformation efficiency and allowable maximum temperature tend to obey the law of diminishing returns, and invariably need lengthy development. Immediate benefits can be obtained from the introduction of modifications into the simple gas turbine cycle. Thermodynamically, variations of the cycle belong to one of two fundamental types. A substantial gain in efficiency of the cycle can be obtained if both the compression and the expansion transformations from and into mechanical energy are conducted near the isothermal process. In practice this is achieved by intercooling between the stages of the compressor and multi-stage combustion between the stages of a turbine. The second type of cycle variation is regeneration, namely, the use of the waste heat in the turbine exhaust for replacing some of the heat added by combustion between the compressor and the turbine. This is accomplished in a heat exchanger of the air-to-air type.

Other varieties of the thermodynamic cycle and of its embodiment in a practical installation are favoured by operational considerations unrelated to peak efficiency. Operation at part loads and the rotational speed characteristics of the driven machine may be decisive.

There are many dozens of variants of gas turbine plants and the majority of commercial and experimental installations built, tested and operated in recent years are more or less extensive departures from the simple " open " gas turbine plant. Clearly, extensive analysis is needed even to begin a selection among this multitude. Not only is the number of types of installation large, but each type of the more complicated kind has even more basic design parameters than the simple installation. Indeed, even the analysis needs an effort so extensive that it can only be fruitful when associated with a particular application and the whole economical aspect of the project is taken as a criterion.

At this point it is appropriate therefore to mention Soviet ideas on the application of gas turbines. In considering power plant applications the type of fuel is a primary concern. In British and American development, the use of coal base fuels, residual oils and natural gas is a decisive element in the assessment of a gas turbine plant. It appears that the economic considerations in the Soviet Union are similar and great emphasis is laid on the use of coal base fuel in particular. In both spheres it seems that distilled oil base fuels are ruled out on any but a small scale and under exceptional circumstances. In the U.S.S.R. there does not seem to be any surplus of residual oils and the great corrosion difficulties associated with this fuel have not been tackled.

In the opinion of one Soviet authority, two widely discussed methods of avoiding the difficulties associated with the use of solid fuel in gas turbine installations are not economically promising. Gasification in gas generators is said to be responsible for losses of fuel energy amounting to 15 per cent, and to increase the size, complexity and operating costs of the installation to such an extent that the principal attraction of a gas turbine installation is eclipsed by the auxiliary plant. We shall mention below that the closed-cycle installation is criticised on account of its high first cost. It is argued, therefore, that the development of gas turbine combustion equipment suitable for pulverised coal is a highly desirable task, in spite of the many obstacles which lie in the way of this development.

Nevertheless there is no evidence of original Soviet work in this direction. The main immediate field of application for stationary gas turbines is considered to be in the generation of power which forms part of certain processes in the metallurgical and petroleum industry. In association with blast furnaces, where combustible gas of low calorific value must be utilised and large quantities of compressed air are needed, Soviet technicians expect to find a field of application for gas turbines where their advantages are particularly telling. Another branch in the utilisation of power resources where good prospects exist for gas turbines is underground gasification. This form of coal winning has for a long time been considered by Soviet technicians as the future form of coal mining, and some of the first practical full-scale tests in the early thirties were carried out in the Russian coalfields. The first Soviet experiments with gas turbines were directly stimulated by these projects.

Soviet engineers also foresee the use of gas turbine prime movers in land and marine transport, but no original work on gas turbine locomotives or gas turbine propelled vessels has been reported.

Although it is stated that in the conditions of planned economy gas turbine plant ought to find extensive applications, the scale of the Soviet effort in the development of gas turbines is not particularly impressive. The work seems to be confined to two or three experimental units, compared with about eighty units built by eighteen firms, in Great Britain, the U.S.A. and Switzerland.

An analytical evaluation of every major form of the gas turbine cycle has been made by Soviet institutions. It appears that two-step combustion in an installation using two gas turbines aggregates is a favoured solution, since this version of the gas turbine plant does not appreciably depart from the inherent simplicity of the ordinary gas turbine.

The degree of regeneration expressed by the percentage of heat removed from the exhaust gas is an important variable in the design of gas turbine installations relying on the regenerative cycle for their efficiency. The high degree of regeneration required for appreciable gains in efficiency leads to a novel order of magnitude in the design of air-to-air heat exchangers. This design today invites the application of new principles of construction. There is no evidence of outstanding achievements in this field in Soviet technology. On the basis of conventional heat exchangers of tubular steel construction, and taking into account the prevailing price structure of power, materials and labour, the Moscow Institute of Power has nevertheless come to the conclusion that the employment of rather high degrees of regeneration, namely up to 0·9, is economically justified.

The Swiss development of the closed-cycle gas turbine plant has been studied in Russia. It is pointed out that in this type of installation the heat exchange surface of the regenerator is of the same order as that of a steam boiler for a power unit producing the same electrical energy. Altogether the bulk and cost are only slightly below those of a steam power plant and, in particular, according to the Moscow Power Institute, the cost of the regenerator, owing to the employment of alloy steel to withstand the high temperature of operation, considerably exceeds the cost of an equivalent steam boiler.

Although the achievements of Soviet gas turbine development cannot be described as outstanding, in the present state of experimental development some details of a gas turbine installation of original Soviet design may be of interest. The set which delivers 1500 kW shaft power at 5000 rpm is designed for an inlet temperature of 600° C and a pressure ratio of 4·6, but in the initial phase a temperature of 550° C and a pressure ratio of 3·4 will be employed. At first the turbine consists of five reaction stages, and a further stage will be added for operation at 600° C.

The turbine rotor is a solid drum of 500 mm diameter, (maximum attainable in forging). It is provided with a central bore of small diameter in order to check the soundness of the forging. Compressed air is introduced to cool the face of the rotor drum on the gas inlet side and escapes partly into the turbine inlet and partly through a labyrinth seal which surrounds the rotor shaft. The exhaust end of the rotor drum is also sealed by a labyrinth gland provided with a central

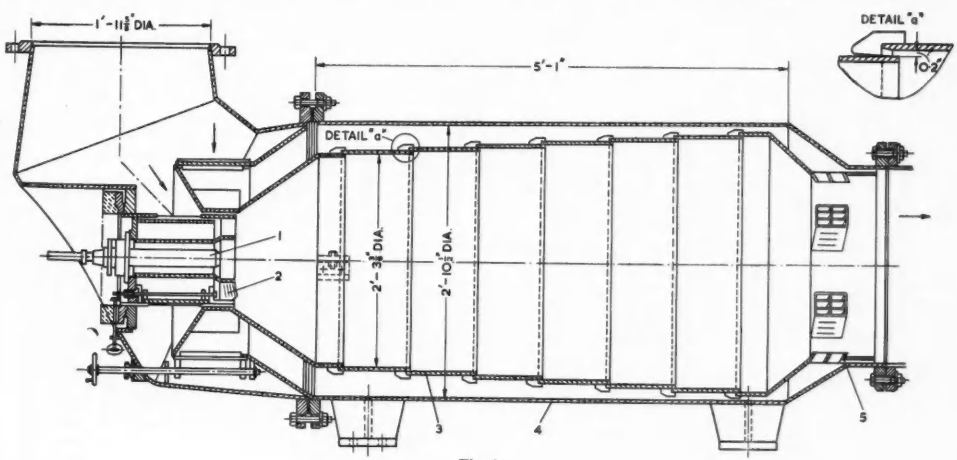


Fig. 1.

annulus connected to the compressed air supply. This ensures that no exhaust gas escapes from the turbine casing.

The stator vanes are held in a separate stator ring clamped in the turbine housing along the narrow edge of a flange. This gives a maximum freedom for expansion. The turbine housing is split horizontally and is made of molybdenum steel. The method of mounting on its foundations provides for the usual freedom for expansion as practised in steam turbine design. There is a by-pass connection between the inlet and the exhaust spirals of the housing, normally shut off by means of a by-pass valve. In the event of failure the by-pass valve is automatically opened and the hot gas is admitted directly to the exhaust.

An axial compressor incorporating sixteen stages is connected with the turbine by means of a rigid coupling. The compressor is laid out for an air flow in the same direction as the turbine. This provides a certain degree of end thrust compensation but a Michell type thrust bearing situated at the far end of the compressor shaft is nevertheless necessary. All main bearings are sliding bearings, pressure-lubricated with an excess amount of oil to ensure cooling in the vicinity of hot casings.

A second unit to operate as a superimposed unit in conjunction with the one described has also been built. Its maximum pressure is 7·9 atmospheres and its turbine inlet temperature is 700° C. This unit is designed purely as a booster unit and does not deliver useful power. Its single-stage turbine of 600 mm tip diameter delivers 2,600 kW at 8,100 rpm. The turbine has an overhanging disc type rotor integral with its shaft directly coupled to an eight-stage axial compressor of 508 mm tip diameter. The whole rotating assembly rests on three sliding bearings without separate thrust bearings.

The turbine is laid out for central gas inlet and an annular exhaust space, an arrangement which is a reversal of the lay-out familiar from turbo-jet units for aircraft. The inlet tube and the housing of the turbine are made with double walls separated by insulating material. The inner walls have relief openings and are thus not subjected to pressure loads and exposed only to the high temperature of the inlet gas. The outside walls carry the pressure loads but have a much lower temperature (200° C). External heat insulation is also provided to reduce the heat losses.

An example of a combustion chamber of original Russian design is shown in Fig. 1. The chamber consists of a flame tube (3) and the cylindrical outer casing (4). The air entering the chamber branches into two streams. Part of the air enters the channels formed by the turning vanes (2) into the inner space where the combustion of the fuel entering through burner (1) takes place. The secondary air, usually the larger part of the total stream, flows in the annular channel between the flame tube and the outer casing. The flame tube is constructed in the form of separate rings telescoping into each other with a small clearance as shown in the detail *a*. The cooling air is progressively mixed with the products of combustion inside the flame tube by entering through the successive annular slots between the telescoping tubes.

At the exit end of the chamber, the products of combustion emerging from the inside of the flame tube meet the remainder of the cooling air stream which enters the central stream through nozzles (5) which impart a swirl to the cooling air. In this manner a thorough mixing takes place to reduce the temperature of the gas uniformly to the admitted maximum. The combustion chamber design shown in Fig. 1 is intended for a pressure of four atmospheres and a temperature of 600° C.

A gas turbine plant can be controlled entirely by regulating the fuel supply to its combustion chamber. The price for this simplicity of control is a considerable reduction in cycle efficiency at part load if the machine has to be maintained at constant speed. Many modifications of the basic cycle have been motivated mainly by the desire to improve part-load performance. No outstanding Soviet solutions to this problem have come to light which are unknown outside Russia.

The control system of a gas turbine must maintain constant rpm and incorporate a number of devices needed for certain emergency conditions. A simplified diagrammatic presentation of the control system for the turbine installation described above is shown in Fig. 2. Variation of fuel supply into the combustion chamber is achieved by displacement of the burner needle (1). The position of the needle is ultimately controlled by the displacement of the piston in the pressure governor (2), which responds to the following speed-sensitive system.

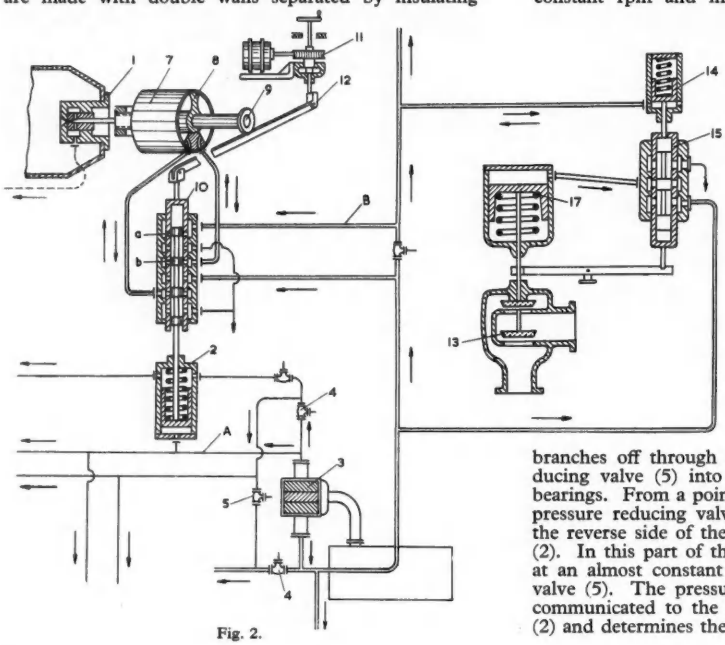


Fig. 2.

An oil pump (3) driven through a gear train from the turbine shaft delivers pressure oil under a pressure of 5 atmospheres into the delivery pipe *A*. Oil also branches off through a constant orifice (4) and a reducing valve (5) into the supply line to the turbine bearings. From a point between the orifice (4) and the pressure reducing valve (5) the oil also has access to the reverse side of the piston in the pressure governor (2). In this part of the circuit the oil pressure is held at an almost constant value by the pressure reducing valve (5). The pressure drop across the orifice (4) is communicated to the piston of the pressure governor (2) and determines the position of the piston loaded by

an internal spring. Clearly, this pressure difference across (4) and, correspondingly, the displacement of the regulator piston are proportional to the square of the delivery from the oil pump, and, therefore, to the square of the turbine speed.

The regulator piston determines the position of the piston valve which controls the vane type rotary servomotor (7). Displacement of the piston valve (6) causes the right or left-hand segments inside the servomotor to communicate either with the oil pressure line or with the oil reservoir. According to the direction of displacement of piston valve (6) the vane (8) of the servomotor turns right or left and thereby advances or retracts the needle which controls the fuel nozzles in the burner (1). Positional correspondence between the servomotor and its control valve is ensured by the mechanism consisting of a cam (9) co-operating with a lever, to which is attached the intermediate sleeve (10) in the servo-control valve. This arrangement ensures that the servomotor (7) moves exactly by the amount determined by the displacement of the piston valve (6) and, hence, of the pressure governor piston. The lever and sleeve mechanism is also used to introduce a manual datum control of the turbine. The manual adjustment consists in changing the position of the fulcrum (12) of the lever and thereby altering the positional correspondence datum between the control valve and the servomotor.

In the event of a sudden collapse of the load, the resulting rise in the turbine rotor speed raises the piston valve (6) and increases the opening of the slot (*a*) through which a constant communication is established between the oil pressure line *B* and the reservoir. The pressure in the line falls, and this causes a drop of the piston of the intermediate servomotor (14) which, in turn, actuates the control valve (15) and thereby the servomotor (17). This servomotor acts directly on the by-pass valve (13) between the inlet and exhaust of the gas turbine.

The control system also incorporates other details not shown in Fig. 2. A limit governor cuts off the fuel supply completely when the turbine speed reaches a value 10 per cent above the maximum permitted in operation. Simultaneously the by-pass valve (13) is opened.

An increase in the gas temperature by 15° C above the maximum sets in motion another limit governor which performs the same operations of shutting off the fuel supply and opening the by-pass valve.

ITALY

The Design of Jet Ejectors

By M. MEDICI. (From *Il Calore*, Vol. 23, No. 11, November, 1952, pp. 556-565, 13 illustrations.)

EJECTORS operating with compressible fluids (such as steam, air, etc.) are of extremely simple appearance, are easy to operate and do not involve high manufacturing or operating costs. These ejectors are extensively used in a wide range of applications, in spite of the fact that their mean efficiency is generally rather low. The reason for this is that an ejector is designed for certain operating conditions. If these are varied, a change may occur in the vacuum conditions at the entrance of the apparatus, and this results in an appreciable decrease in efficiency and in ejector output.

A consideration of these facts led M. Leblanc, one of the earliest exponents of the use of steam ejectors as vacuum pumps, to suggest the construction of an apparatus with articulated or deformable walls, which could be modelled according to the actual shape of the stream of fluid in the ejector. Owing to difficulties encountered in regard to the mechanical strength of the models, this suggestion was not pursued any further at that time.

In making an analysis of a jet ejector, it is necessary to consider the overall behaviour of the apparatus and the way in which this is affected by the design features and operating characteristics of the component parts. These can be listed as follows: (1) the nozzle discharging the primary stream; (2) the inlet tube for the secondary stream; (3) the mixing tube; and (4) the diffuser at the end of the apparatus. In the following, each of the component parts will be considered individually.

THE PRIMARY NOZZLE

The shape and geometry of the ejection nozzle for the primary or actuating stream cannot be completely determined by calculations. Although with the energy equation and an entropy diagram an evaluation can be made of the stream velocity and the thermodynamic condition of the fluid at various positions in the nozzle, it is not possible to establish the law of pressure variation in the first stage of a design. Instead, the usual procedure is to assume a law of pressure variation, which is then modified gradually to suit technical requirements and to combine efficiency with maximum flexibility under different operating conditions. The earliest nozzles were of the De Laval type. The shape was modified somewhat by Stodola, in order to obtain better operation at partial loads.

An extensive and methodical investigation recently carried out at the laboratories of the Compagnie Delas, near Paris, has made it possible to establish the effective pressure variations which occur in the nozzles and expansion tubes of ejector apparatus.

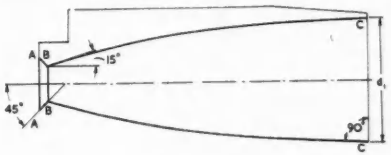


Fig. 1.

The investigation was made with jets containing powders of abrasive substances in suspension, which were used to produce in the metal the shapes and contours which were to be determined. These are of the type shown in Fig. 1. The nozzle should thus consist of a conical inlet (section *A*-*B*) with a 45 deg. taper, and a constriction at point *B*, followed by a longer bell-shaped section *B*-*C*. The angle of the divergent portion with the nozzle axis should be about 15 deg. at point *B*, varying gradually along the contour until it becomes zero at position *C*, where the stream comes out in straight lines parallel to the nozzle axis.

The throat diameter and the dimensions of the divergent portion are determined by formulae derived from the energy equation. The nozzle diameter at *B* (minimum area) is given by

$$d_{\min} = \sqrt{(4/\pi)\, M_v/[B\sqrt{p_o v_o}]} \quad \text{[metres]} \qquad (1)$$

where $B = 1{\cdot}99$ for wet steam with $\gamma = 1{\cdot}135$, and

$B = 2{\cdot}09$ for superheated steam with $\gamma = 1{\cdot}3$. In this equation, M_v = rate of mass flow [kg/sec] of primary stream, p_0 = inlet pressure [kg/m²] of primary, and v_0 = specific volume of primary at the inlet [m³/kg].

The velocity of the primary stream at the constriction is obtained from

$$c_{cr} = C\sqrt{p_0 v_0} \qquad \text{[m/sec]} \qquad (2)$$

where $C = 3{\cdot}23$ for wet stream ($\gamma = 1{\cdot}135$), and $C = 3{\cdot}33$ for superheated steam ($\gamma = 1{\cdot}3$). The velocity at the exit is

$$c_1 = \sqrt{8380 \times \Delta i\,(1 - \zeta_E) + c_0^2} \text{ [m/sec]} \qquad (3)$$

c_0 being the inlet velocity, while Δi = decrease in enthalpy [kcal/kg] in the divergent portion, and ζ_E = relative value of the energy losses in the divergent portion. The diameter at the exit is determined as

$$d_1 = \sqrt{(4/\pi)\, M_v v_1 / c_1} \qquad \text{[metres]} \qquad (4)$$

where v_1 = specific volume of primary vapour [m³/kg] at exit of the divergent portion.

For expansion sections with a simple bell shape (Fig. 1), the length-to-diameter ratio should be about $l/d_1 = 2{\cdot}5$-$2{\cdot}75$, d_1 being the exit diameter. For tubes with several bell-shaped sections, the overall length should be about 4 times d_1 (exit diameter), with sectional lengths determined by $l_1 \sim 2d_1$ and $l_2 \sim 1{\cdot}8d_1$ for the two bell-shaped portions.

The use of a bell-shaped transition following the conical constriction at the inlet (in which sonic velocity is reached) gives the most favourable design for supersonic flow conditions. By subdividing the tube length into several bell-shaped portions, a certain amount of flexibility is obtained in operation (see Fig. 2). When the ejector operates under its original design conditions, the stream adheres to all the wall surfaces of the bell-shaped sections. If, however, the pressure at the downstream end of the tube happens to increase, the presence of the second constriction (denoted by *r-r* in Fig. 2) causes a breaking away of the flow, so that only the first bell-section ahead of *r-r* is used, thus avoiding excessive expansion, which can cause considerable energy losses and reductions in efficiency in the apparatus. Previously, in order to avoid the occurrence of such conditions, it was usual to make a compromise design, with the result that the length of the divergent portion was sometimes less than the theoretically required value and therefore detrimental to the operating efficiency and ejector output.

Extensive experience gained in the United States and other countries indicates that, for steam ejectors designed for the extraction of air from steam condensers of medium and high ratings, it is an advantage to make use of several ejectors in series, with two or three compression stages. (For saturated steam, typical values are as follows: 1st stage: 70-760 mm; 2nd stage: 10-100 mm; 3rd stage: 1·5-15 mm; and 4th stage: 0·25-2·5 mm Hg.) If the ejector apparatus is of the three-stage type, good results are obtained by using a divergent section with three bell-shaped portions for the first stage, and two bell-shaped portions for each of the other two stages.

THE INLET TUBE FOR THE SECONDARY STREAM

The shape of the inlet tube for the secondary or entrained stream, which is connected to the straight mixing tube, is of considerable importance, since it affects the overall efficiency of the ejector.

The study of supersonic flow, or flows approaching the sonic velocity of the medium, is an intricate subject. Schlieren investigations, which make it possible to determine the density fluctuations in the fluid by optical methods (using interference and refraction phenomena in the fluid) are a useful complement to the normal methods using pitot tubes, etc., for the determination of static pressure at various positions.

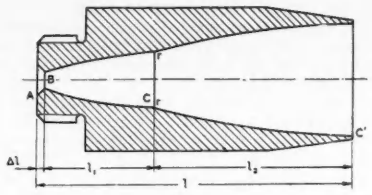


Fig. 2.

Schlieren investigations carried out a few years ago by J. Chalom,* of the Delas Co., showed that, for compression ratios of about 2:1, the best ejector efficiencies are obtained when the secondary stream reaches a velocity close to the sonic velocity of the medium, at the beginning of the mixing tube. Consequently, from Chalom's results it appears that the most suitable type of inlet tube for the secondary stream is a design with a bell-shaped contour, arranged as a convergent section, with its larger diameter facing the outlet of the nozzle expansion tube (Fig.3).

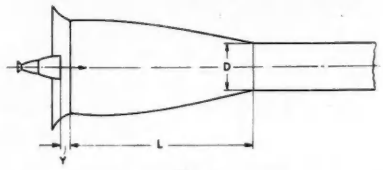


Fig 3.

However, another type of design has been proposed by Keeman, Neumann and Lustwerk, of Cambridge, Mass., U.S.A., as a result of research work using air as the working medium.† These investigators made comparative tests of three types of secondary inlets and mixing tubes, viz.:

(a) a 20 deg. conical convergent inlet ($L = 3{\cdot}6$ in., $D = 1$ in.) followed by a straight mixing section ($L = 3{\cdot}6$ in.);
(b) a parallel inlet ($L = 6$ in., $D = 1{\cdot}5$ in.) followed by a 15 deg. conical convergent section up to a diameter of 1 in.;
(c) a 4 deg. conical convergent inlet ($L = 7{\cdot}2$ in., $D = 1$ in.);

they used a 3 deg. conical diffuser after the mixing tube in all three cases. Best results were obtained with the arrangement (c), which has a good efficiency for supersonic flow, and preference was therefore given to this design.

This investigation covered a range of pressure ratios p_1/p_2 reaching up to 200 (where p_1 = pressure of primary fluid, and p_2 refers to the secondary fluid). The tests showed that with increasing values of p_2/p_1 it is necessary to increase the distance Y (see Fig. 3) between the exit of the divergent portion of the primary nozzle and the secondary inlet. Flow fluctuations at supersonic velocities can cause variations in the value of the rate of mass flow ratio M_2/M_1. These tests were made using nozzles of 0·1 and 0·2 in. diameter at the throat section, and circular-section mixing tubes of 0·4, 0·6 and 1 in. in diameter.

The influence of the distance Y between the primary nozzle exit and the secondary inlet was also confirmed by Chalom's tests and other investigations made on

*See: C. Cabanes & J. Chalom: Contribution to the experimental study of supersonic flow; application to steam type ejectors. Assn. Tech. Arts & Métiers, Paris, 1949 Session.

†See: H. Keeman, E. P. Neumann and F. Lustwerk: An investigation of ejector design by analysis and experiments. *J. Appl. Mech.*, 1950, No. 3, Sept., pp. 299-309.

this side of the Atlantic. Other conditions being equal, it was found that there are optimum values of $(L + Y)/D$ for various values of the pressure-ratio in order to obtain high rates of mass flow for the entrained secondary fluid. These values are indicated in the following table:—

p_1/p_2 =	2	5	10	20	50	100	200
$(L + Y)/D$ =	7·5	11·5	12·5	14	15	15·8	16

Thus, using the arrangement (c) described above, with a pressure ratio $p_1/p_2 = 200$ and a diameter ratio D/d_{cr} (d_{cr} = nozzle throat diameter) of 25, it was found that maximum rate of mass flow ratios M_2/M_1 were obtained with a Y/D ratio slightly greater than 8.

THE MIXING TUBE

The necessity of having a straight-section mixing tube between the usually convergent secondary inlet and the divergent diffuser was first pointed out by the author some 15 years ago. The importance of this straight mixing section was confirmed by subsequent analytical investigations, particularly those of Flügel and Tessari, and by experiments in the Machines Institute Laboratory of Padua University, carried out under the supervision of the author. The mixing tube should have extremely smooth inner surfaces and any subsequently occurring surface roughnesses have a detrimental effect on performance.

Unfortunately, no analytical expression has yet been developed for the direct determination of the optimum length of the mixing tube. This length depends on operating conditions and a number of factors such as turbulence, boundary layers, diffusion, etc. With multi-stage ejectors it is necessary, therefore, to have a different mixing-tube length for each stage.

The following equation indicates the pressure increases obtainable as a result of an adiabatic change of state with a velocity c_i in the inlet section of an ejector diffuser:—

$$\frac{p_3}{p_1} = \left[\frac{c_i^2}{2gc_p T_i} + 1\right]^{\gamma/(\gamma-1)} = \left[\frac{\gamma - 1}{2} M c_i^2 + 1\right]^{\gamma/(\gamma-1)}$$

where T_i = absolute temperature at diffuser entrance, c_p = specific heat at constant pressure, and M = rate of mass flow of the mixture.

For $p_1/p_2 = 11{\cdot}24$, $L/D = 12{\cdot}28$, $D_2/d_{cr} = 2$, and $Y/D = 1{\cdot}5$, Keeman and his collaborators determined a graph showing the increase in pressure p_x/p_2 obtainable in mixing tubes of relative lengths x/D, for various values of the rate of mass flow ratio M_2/M_1. Typical values are indicated in the following table.

TABLES OF VALUES OF p_x/p_2

x/D =	0	1	5	10	14
M_2/M_1 = 0·46	1·0	1·0	2·3	3·3	3·3
0·81	1·0	0·95	2·05	3·1	3·15
1·31	1·0	0·8	0·8	2·8	2·8

Other graphs by the same authors indicate the values of M_2/M_1 and D_2/d_{cr} related to the pressure ratios p_1/p_2 and p_3/p_2.

THE DIFFUSER

If the pressure of the primary entraining fluid is very high, it is advisable to use a diffuser of the supersonic type for the slowing down of supersonic velocities (see Fig. 4).

Fig. 4.

In such a case, supersonic compression shocks occur in the section marked X in Fig. 4, and behind this the flow is at subsonic velocities. To slow down these velocities, and to obtain a good conversion of kinetic energy into pressure, the diffuser is designed with a constriction followed by a divergent diffuser section.

Otherwise, the diffuser is designed as a divergent cone, and good results are obtainable by using the following proportions:—

Area ratio $S_{in}/S_{exit} = 2$ and $L/D = 3{\cdot}6$ for a single-stage ejector, or for the first stage of a multi-stage design;

$S_{in}/S_{exit} = 6{\cdot}7$ and $L/D = 10{\cdot}75$ for the second stage of a two-stage ejector with condensation chambers between the stages and at the exit.

GENERAL DESIGN CRITERIA

The design is usually based on the value of the rate of mass flow of the fluid to be extracted, for given values of pressure at the entrance and exit of the apparatus. For steam ejectors, the value of M should also include the uncondensed fluids mixed with the steam. The extraction capacity depends on the initial values for pressure, temperature and enthalpy of the primary actuating fluid. As wet steam has an unfavourable effect, steam-jet ejectors should always be designed for sufficiently superheated steam. Excessively high pressures for the primary stream should be avoided, since the minimum-area section of the diffuser is then too small to allow the full ejector output.

Under starting and other operating conditions, the required output and the pressure at the ejector entrance differ considerably from the values used as a basis for the design. The behaviour of ejectors under varying conditions is, therefore, of considerable interest. The following table for steam ejectors indicates the ejector performance as a function of absolute pressure at the ejector entrance.

p_{abs}	0·0	0·015	0·05	0·1	0·15	0·2	0·24	atm abs
	Extraction capacity (per cent)							
Single-phase	—	—	0	60	120	170	200	
Two-phase	0	25	95	125	—	—	—	
Three-phase	0	100	140	—	—	—	—	

These figures show that it is necessary to use two-stage ejectors to maintain vacuum values above 90 per cent ($p_{abs} \leq 10$ per cent) and three-stage ejectors for vacuum above 97·5 per cent (p_{abs} below 0·025 atm abs). If the ejector is designed for low specific consumption of the primary fluid, with 2nd and 3rd stages (and their condensers) limited to the economic load, the vacuum values under overload or continuous maximum load conditions will be considerably reduced when the load is increased.

It is advisable to employ ejectors with multiple elements for each stage. Elements operating in parallel give additional flexibility under varying load conditions as well as a much higher capacity during the starting period. The additional parallel elements required for starting can be put out of circuit when the apparatus reaches its normal load.

At the design stage, it is usual to assume a gauge pressure of 0·07 atm for the ejector exit and to provide for ejector operation over a fairly wide range of primary inlet pressures (for instance gauge pressures of 18-20 atm and a maximum of 60-120 atm). At present, the most widely used range of pressures is between 38 and 46 atm gauge. The primary-fluid temperature is usually about equal to superheating temperature or slightly below this value.

FRANCE

The "Aerojet Venturi" Micro-Mist Purifier

By R. M. G. BOUCHER. (From *Chaleur et Industrie*, Vol. 33, Nos. 328 & 329, November & December, 1952. pp. 363-377 & 425-430, 15 illustrations.)

This article describes the Aerojet Venturi apparatus and its industrial applications. It also gives the results of the author's investigations of aerosols of various types as well as a correlation of experimental data with theoretical considerations.

THE study of mixtures of aerosols and mists covers a wide field and includes such applications as carburetter injection systems, liquid fuel burners, and purifiers for industrial gases and fumes. Although mainly the latter applications are considered, the results should also be useful in other fields.

DESCRIPTION OF APPARATUS

A drawing of the Aerojet Venturi apparatus operating in conjunction with a cyclone collector is shown in Fig. 1. The gas to be purified (the "primary aerosol") is introduced into the inlet of the convergent-divergent element. By means of compressed air (at 1-7 kg/cm²) or vapour under pressure, a liquid is sprayed by an atomiser in the form of a mist into the throat section of the unit. This mist or "secondary aerosol" can be given a high negative charge by applying a negative potential to the spray generator casing. An additional mist generator can be arranged, as shown in the figure, in the counter-flow direction immediately ahead of the cyclone inlet. Mixing occurs mainly in the throat section and in the divergent portion of the apparatus. The resulting mixture at the divergent outlet shows a mean particle size which is many times greater than that of the original primary aerosol.*

It should be noted that in this arrangement the secondary mist is adjusted to have a mean particle size giving maximum agglomeration with the solid or liquid particles of the primary aerosol. The coarser and heavier particles thus obtained can then be captured by impact separators or cyclones of conventional type at moderate cost, with a considerably increased efficiency.

IMPACT AND DIFFUSION OF PARTICLES

Collisions between minute particles suspended in streams of gases are mainly due to directed impact and diffusion. In aerosols with a mean particle diameter below 0·5 μ, for instance, Brownian motion is the predominant factor. A particle of 1 μ diameter falls through 600 μ in 20 sec, while its Brownian motion has an amplitude of 30 μ. A particle of 0·1 μ has a Brownian amplitude of 96 μ and only falls through 6 μ in 20 sec. The laws governing gas mixtures can be used to calculate the rate of diffusion of fine particles on the surface of a droplet. It is assumed that the particles reach the surface through a stationary layer, the thickness of which depends on gas velocity, the shape of the droplets, etc. For spherical droplets, for instance, the agglomeration efficiency due to diffusion can be calculated from

$$\gamma = 4\,D_v/(xU)$$

where x = film thickness (a function of Reynolds' number and Schmidt's number), U = particle velocity, and D_v = diffusion coefficient of the fine particles. The latter is obtained from

$$D_v = (kT/3\,\pi\,\mu\,d)\,[1 + 1{\cdot}72\,(\lambda/d)]$$

where k = Boltzmann constant, T = absolute temperature, μ = dynamic viscosity of gas, d = particle diameter, and λ = mean free path of Brownian motion.

The agglomeration of particles by direct impact (with non-elastic collisions) was first investigated mathematically by Sell [1] who used step-by-step calculations to determine the particle trajectory between two impacts, for three types of obstruction (sphere, plate and cylinder). The expressions obtained are of the exponential-decay type, with terms depending on particle mass and angle of direction. More recently, the investigations of Brun, Demon and Vasseur [9] seem to have provided a firmer basis. There are discrepancies in Sell's assumptions concerning the uniformity of the flow lines of the fluid, which were discussed by Albrecht [3]. Moreover, Sell does not take account of the boundary layer, so that his calculations are invalid for distances very close to the surface of the obstacle.

In 1945, Brun, Vasseur and Caron [2] published a paper giving the following general equation of motion of a particle in the vicinity of an obstacle:—

$$\rho d\mathbf{U}/dt - \rho'\,d\mathbf{U}'/dt = -\rho'\,(u/d)\,\mathbf{u}\,f(Re) + \rho\mathbf{H} - \rho'\mathbf{g} \quad (1)$$

where $\mathbf{U}$ = particle velocity, $\mathbf{U}'$ = fluid velocity (both at any point M considered), $\mathbf{u} = \mathbf{U} - \mathbf{U}'$ = relative particle velocity, ρ = mass density of particle, ρ' = mass density of fluid, d = characteristic dimension of particle, $Re = ud/\nu$ Reynolds' number for relative flow of liquid, $\mathbf{g}$ = acceleration due to gravity, $\mathbf{H}$ = acceleration due to field acting on particle (such as a sonic field); if no other field effect is present, $\mathbf{H} = \mathbf{g}$. The bold-type symbols denote vector quantities.

Considering the case of an aerosol in the neighbourhood of an obstacle (such as a plane, a cylindrical wire or another droplet), it is seen that the velocities $\mathbf{U}$, $\mathbf{U}'$ and their derivatives $d\mathbf{U}/dt$, $d\mathbf{U}'/dt$ are of the same orders of magnitude. Moreover, the value of ρ' (fluid density) is small relatively to that of the particle, so

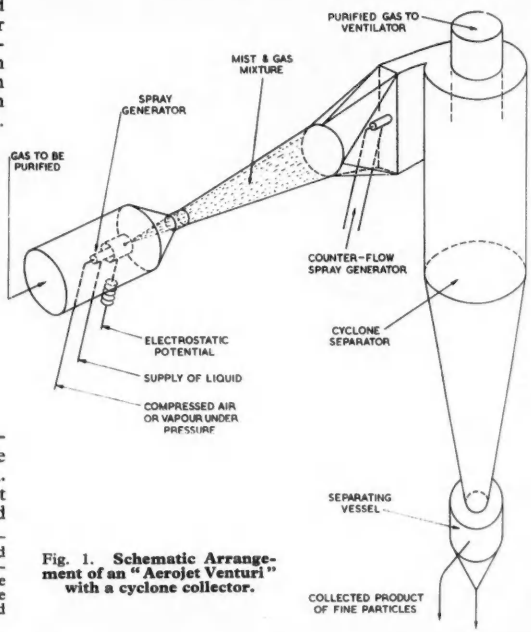


Fig. 1. Schematic Arrangement of an "Aerojet Venturi" with a cyclone collector.

*Although in this study the terms "aerosol," "micro-mist" and "mist" are intentionally used to designate liquid or solid dispersions of any particle size, it would be most desirable to reserve the term "aerosol" for particle dispersions with a mean size below 1 μ, "micro-mist" for sizes between 1 μ and 100 μ, and "mists" for coarse emulsions, etc.

that, if we also disregard the force of gravity in comparison with the inertia forces, eq. (1) may be simplified to:

$$\rho\, d\mathbf{U}\, dt \quad -\rho'\,(u\ d)\,\mathbf{u}\, f(Re) \quad .. \quad .. \quad (2)$$

Brun and Vasseur [4] resolve this vector-equation into its tangential and normal components, viz.:

$$UdU/dt = (\rho'/\rho d)\,(U' \cos\alpha - U)\, u\, f(Re) \quad (2')$$

and $$U^2/R = (\rho'/\rho d)\, U' \sin\alpha\, u\, f(Re) \quad .. \quad (2'')$$

R being the radius of curvature of the trajectory at the point M. It is thus possible to determine R from eq. (2''), by using the relation

$$u^2 = U^2 + U'^2 - 2\,UU' \cos\alpha$$

By means of eqs. (2), (2') and (2''), we were able to calculate the trajectories, point by point, for particles of different masses and sizes, using finite differences. These theoretical figures were then compared with the experimental values. The calculations with eq. (2) were also repeated with the inclusion of the term taking account of gravity. The results showed that its omission is permissible for 10 μ particles with velocities above 20 m/sec, but that gravity must be included for velocities of the order of 1 m/sec to obtain reasonably good results.* The trajectory of a 30 μ particle having the same size and velocity at a remote point gave a much lower point of impact than the lines for the lighter particles, even though its starting position was more favourably situated.

The "capturing efficiency" γ will be defined as the ratio $\gamma = m/m_o$, following Brun, Caron and Vasseur, where m = total mass of particles impinging upon the obstacle per unit time, and m_o = total mass of particles passing the obstacle and situated in the cylindrical volume formed by lines parallel to $\mathbf{U}_o$ (the velocity at a remote point) and circumscribing the obstacle.

The flow pattern around an obstacle can easily be constructed [6] using a complex velocity potential: $f(z) = \varphi + i\psi$, and the streamlines related to particle sizes by means of the trajectories previously calculated. In this way, it is possible to determine γ by calculation. Each type of flow can be defined by giving fixed values to the quantities U_o, ρ, ρ', d and D (d = particle diameter, and D = diameter of obstacle). Considerable simplification is obtained by assigning a fixed value to either D or d, and choosing four other of the six quantities U_o, ρ, ρ', d, D and ν (kinematic viscosity), in such a way as to obtain constant values for the ratios: U_oD/ν, D/d, ρ'/ρ and U_o^2/D. By applying these similarity considerations, it was possible to determine the variation of γ as a function of the particle-size d for different values of the parameters D and U_o. It was found that γ increases steadily from zero to 65 per cent for d-values from zero to 40 μ (D = 0·476 cm, U_0 = 220 cm/sec) and that the curve is slightly steeper for higher U_0-values.

EXPERIMENTAL STUDY OF DIFFUSION AND IMPACT PROCESSES

The flow conditions described in the theoretical investigation given above were reproduced experimentally as follows: A micro-mist was generated by means of a compressed-air sprayer with a liquid consisting of a 50 per cent mixture of glycerin and isobutyl-alcohol. The obstacle was a thin flat sheet of glass (with a characteristic dimension D = 0·476 cm) of considerable size placed about 1 m away from the mist generating unit and arranged with its thin edge perpendicular to the jet axis.

To assess the values of the capturing coefficient γ, impact tests were made with the glass plate covered, (i) with a thin layer of castor oil (Häuser-Strohl method [7]), and (ii) with vaseline (Houghton-Radford method [8]), and the results were compared with those of further tests using a plexigum-wire network (Brun, Demon and Vasseur method [9]) under similar flow conditions. In these latter tests, the network consisted of parallel micro-wires of 1-2 μ diameter, spaced only a few microns apart, and fixed on a supporting ring. As the particles in the artificial mists were close to micron size, the distortion of the aerodynamic field in the proximity of the grid was reduced to a minimum value. Two samplings were taken for each type of mist investigated and the impacts on the glass plate or grid were examined microscopically (with × 200 magnification) a few seconds after capture, in a saturated atmosphere.

The test results led to the following conclusions:—

1. The capturing coefficient γ is a function of U_0D/ν, D/d, and ρ'/ρ.
2. The value of γ increases with increasing values of U_0 for particles larger than 10 μ. With very fine particles, γ is not affected by U_0, contrary to theory. This may possibly be due to an interpenetration of the trajectories, which is more likely to occur with minute particles, and to effects of electric charges.
3. The grid technique is a considerable improvement and eliminates some of the possibilities of errors occurring with the glass plate method for particle sizes of the order of 1 μ [10]. The results show that accurate counts are not achievable for particle sizes below 5 μ, so that γ has to be confirmed theoretically in such cases. The grid arrangement produces less disturbances and conforms more closely to the basic requirements. As a general rule, therefore, impact measurements are no longer reliable when the particle size is below 5 μ.
4. As each particle acts both as a projectile and as an obstacle with regard to neighbouring particles, in the mixing of two dispersed phases, the probability of efficient impact (i.e., impact followed by agglomeration) is greater for particles having the same diameter than for particles of different size. This can easily be inferred from the above considerations regarding the capturing coefficient. Similarity in size thus leads to improved agglomeration efficiency, a noteworthy result.
5. Not only the grain-size distributions, but also the average number of particles per unit volume of the two aerosols should be as nearly the same as possible, in order to obtain maximum particle agglomeration in a minimum time.† This fact has been verified experimentally by the author in laboratory tests with tubes and tunnel arrangements. It was also confirmed by subsequent tests of aerosol mixtures using the Aerojet Venturi apparatus.
6. The agglomeration phenomena of particles smaller than 1 μ in size are different from those for larger particles. For sub-micron particle dispersions, conclusion (4) is again valid (similarity of size-distribution) but conclusion (5) does not apply. Instead, it should be emphasised that in order to obtain a high agglomeration efficiency with sub-micron particles, it is necessary to mix with the primary aerosol a secondary aerosol with a particle density 8-10 times greater. The time of contact must also be increased, owing to secondary effects caused by evaporation and the vapour tension of liquids.

GENERATION OF MICRO-MISTS AND THE MECHANISM OF AGGLOMERATION

To obtain maximum efficiency with an apparatus such as the Aerojet Venturi, it is necessary, in view of the above considerations, to generate a secondary micro-

*Simplified calculations were possible by means of the following theorem: The curvature $1/R$ of the trajectory at a point M is equal to the curvature obtained disregarding gravity plus the curvature $1/R_2$ which would be obtained if the vectors $\mathbf{U}$ and $\mathbf{U}'$ were both in the same direction. The correction term used is therefore a function of the angle between the two velocity vectors.

†See French Patent No. 986,566.

mist having a suitable particle density and grain-size distribution. As industrial aerosol particles frequently have average sizes between 0·1 μ and 5 μ, the micro-mists generated should be of similar particle sizes.

Two main methods are used to break up a jet of liquid into micro-mists of this order of fineness, viz. pneumatic atomisation and solid injection. New techniques, using centrifuging atomisers with a vibrating plate, ultrasonic or high-frequency detonation equipment, have been developed in recent years for special purposes, but have not yet reached their final stage of development.

In pneumatic atomisation, the jet emitted at a low velocity is atomised by a high-velocity air stream, whereas with solid injection the liquid is ejected at a high velocity into a stationary atmosphere. Typical values of droplet diameters obtained with different injection pressures are given by Sass [12]: 20 μ at 150 kg/cm², 15 μ at 200 kg/cm², 10 μ at 300 kg/cm², and 8 μ at 350 kg/cm². Although, owing to the difficulties in exact size determination previously discussed, Sass's values are probably somewhat higher than the actual values, they show that the minimum diameter of droplets obtained with solid injection is very rarely below 4 μ. To obtain micro-mists suitable for industrial applications, we therefore directed our efforts towards pneumatic atomisation. A theoretical study of this subject was made by Littay [16] in 1945.

A micro-mist is fully defined by its frequency distribution curve, from which other important data (such as the specific surface area, average diameter, mean deviation, etc.) can be derived, whereas inadequate information is provided when only a mean diameter or mean deviation is given. It was therefore necessary to define the characteristics of the secondary aerosols emitted by micro-mist generators under operating conditions.

The Japanese investigators Nukiyama and Tanasawa [13] were the first to provide two empirical equations by means of which the fineness of a mist can be related to the operating characteristics of a pneumatic atomiser. The first equation gives the "volume/surface-area diameter" d_{vs}, which is the diameter of a droplet having the same volume/surface-area ratio as all the droplets in the spray taken together:—

$$d_{vs} = 585\left\{\sqrt{\sigma}/(v\sqrt{\rho})\right\} + 597\,[\mu/\sqrt{\rho\sigma}]^{0\cdot455} \times (1000\,q)^{1\cdot5} \qquad (3)$$

where σ = surface tension of liquid [dyne/cm], v = relative speed between gas current and liquid flow [m/sec], μ = dynamic viscosity of liquid [poises], ρ = mass density of liquid [gr/cm³], and $q = Q_L/Q_A$ = ratio of liquid to air flow in the "vena contracta." This equation applies to liquids having a density between 0·7 and 1·2 gr/cm³, a surface tension between 19 and 73 dynes/cm and a viscosity between 0·003 and 0·5 poises. The gas stream is assumed to be flowing at a sub-sonic velocity.

It has been shown by Lewis and his collaborators [14] that this equation gives correct d_{vs}-values in the range defined by $0{\cdot}2 < 1000\,q < 0{\cdot}5$ and it is, therefore, possible to use this equation to determine the degree of atomisation obtained with a pneumatic atomiser injecting liquid radially into the throat of a convergent-divergent element. The second equation of Nukiyama and Tanasawa indicates the particle distribution of micro-mists obtained with pneumatic atomisers. In the form of a frequency-equation it can be written as

$$dn/dx = a\,x^p\,e^{-bx^q} \qquad .. \qquad .. \qquad (4)$$

where x = droplet diameter [μ], n = number of droplets with diameters having values between 0 and x, while a, b, p and q are constants. Generally, $p \simeq 2$, whereas q depends on the homogeneity of the micro-mist and varies according to the type of nozzle used. Large q-values give a sharply-peaked distribution curve, whereas low q-values give a flatter spectrum. The equation is applicable within the limits $130 < v < 300$ [m/sec] and $q > 5000$ but tends to give values somewhat higher than the experimental figures. Owing to the difficulties occurring in the accurate determination of the constants, it was frequently found preferable to use the Rosin-Rammler equation for frequency distribution [15], which gives very adequate accuracy for the plotting of curves of gas-and-liquid mists. This equation can be written as

$$n = 100\,e^{(-d/c)^b} \qquad .. \qquad .. \qquad (5)$$

or in the form

$$\text{loglog}\,(100/n) = b\,\log d - b\,\log c + \text{loglog}\,e \qquad (5')$$

Plotting the number n as an ordinate on a loglog-scale and taking d as the abscissa on a simple logarithmic scale, a straight line is obtained representing the entire distribution. The slope is given by the constant b, which is analogous to the mean deviation, large b-values giving a sharp peak and small b-values a broad and flat spectrum.

Extensive series of tests were carried out to obtain basic data and if possible a correlation between measured and calculated values. The micro-mist was generated with a Kremlin A-2 type atomiser. The liquid was aspirated through a duct with an internal diameter of 2 mm, while the gas was ejected through an annular orifice of 2·6 mm outer diameter. As the mixture reached supersonic velocities in the vena contracta, maximum velocities were determined from flowmeter measurements. The cone of micro-mist had a total aperture angle of about 17°15′ and systematic measurements at various distances from the atomiser showed that a statistically homogeneous mist was obtained only beyond 1 m distance from the apex of the cone. This critical distance was found to vary according to the type of atomiser used. An example of the results obtained is given by the figures in the following table.

COMPARISON OF MEASURED AND CALCULATED VALUES FOR VARIOUS MICRO-MISTS
(Measurements with a plexigum grid at 5 m distance)

Calc. d_{vs}	Measd. d_{vs}	Measd. d_{mean}	No. of particles per gr	Rosin-Rammler coeffs. b	Rosin-Rammler coeffs. c	1000 × q	Flow lit/hr	p_{air} kg/cm²	Aero-jet effi-ciency
106	18·5	3·0	$1{\cdot}45 \times 10^2$	1·36	3·35	2·07	7·1	1·0	88%
136	20·9	3·2	1·14 „	1·31	2·48	2·52	13·3	2·0	87%
153	28·2	3·0	0·51 „	1·01	1·90	2·75	27·5	5·0	93%
146	30·6	2·5	0·50 „	1·02	1·90	2·66	23·2	4·0	92%

The above table includes calculated d_{vs}-values obtained by means of the Nukiyama-Tanasawa equation. Although this equation, in principle, is valid only for subsonic flow velocities and q-values above 5,000, many pneumatic atomisers operate with supersonic velocities and low air/liquid flow ratios (q-values below 500). The table shows a proportionality between calculated and measured values for the range tested, so that we may write

$$d_{vs\ \text{calc}} = K \times d_{vs\ \text{meas}}$$

where K is a constant between 4·1 and 7·1, the most frequent value being $K = 5{\cdot}6$.

These tests showed mean particle diameters between 2·5 μ and 3·2 μ. They did not give any marked correlation between surface tension and the size of the droplets collected on clean glass plates. Littaye [16], on the other hand, had found that the minimum diameter of the droplets was proportional to surface tension and established the following formula for the diameter D_{max} of the largest droplets capable of existing without breaking up:—

$$D_{max} = (4\gamma/0{\cdot}31)\ \sigma/\left\{\rho\,(v_A - v_L)^2\right\} \quad .. \quad (6)$$

In this equation, σ = surface tension [dyne/cm], γ = agglomeration coefficient, ρ = mass density of liquid, v_A and v_L = flow velocities of the gas and liquid particles, respectively. Littaye worked with subsonic velocities and q-ratios above 5,000, and the value of the constant K, for the types of nozzles which he investigated, is somewhere between 2 and 5. This is confirmed by comparing results for similar types of nozzles investigated by Lewis and his collaborators [14], Sauter [17] and Houghton [18]. Thus, we may summarise the findings as follows:—

(i) For Littaye type pneumatic atomisers, operating at subsonic velocities with high q-ratios, the size of the particles is effectively proportional to surface tension, whereas the effect of the latter is less noticeable for supersonic atomisers with q-ratios well below 5,000.

(ii) The Nukiyama-Tanasawa equation is applicable to both types of pneumatic atomisers, with suitable adjustment of the value of the K-constant.

In this connection, it is worth emphasising the fact (observed by Lord Rayleigh [19] and also mentioned by Lane [20]) that two liquids with the same value of surface tension will have a different effect on the particle-size distribution obtained by pneumatic atomisation if one consists exclusively of surface-active molecules whereas the other is a solution comprising such molecules.

Another point to be considered is that Littaye's tests showed that d_{mean} and D_{max} reach small values with increasing air flow velocities. Littaye's results, and those of other investigators, are for q-values above 1,500. With our atomisers, we have been able to obtain good dispersions for q-values ranging from 400 to 1200. In this range, the grain-size distribution follows an exponential law and the diameter varies proportionately to the dynamic pressure (and flow velocity) of the gas stream. This is borne out by the Nukiyama-Tanasawa equation, which shows that for low q-values the first term becomes unimportant, so that the equation reduces to

$$d_{vs} = 597\,(\mu/\sqrt{\sigma\rho})^{0{\cdot}455} \times (1000q)^{1{\cdot}5} \quad .. \quad (7)$$

and this applies to all the micro-mists obtained with our spray generators. Moreover, it was found that, in this range, the maximum diameter of the droplets obtained at supersonic gas velocities is in accordance with the empirical law

$$D_{max} = e^{k\,(v_A - v_L)} + k_1$$

which is in contrast with Littaye's relation for subsonic flow velocities.

Thus, the shape, mechanical features and operating characteristics of the atomising nozzle are extremely important. Our Kremlin type generators use 10 to 20 times less air than conventional atomisers for a given flow of liquid, and reach high values of efficiency. It is therefore possible to conclude that, by reducing to a minimum value the area of the vena contracta of the gas-and-fluid mixture, considerable improvements as regards fineness and operating efficiency can be obtained under certain flow conditions (range of q-values below 1500). Using the A-2 type generator, it is found that the fineness of atomisation is inversely proportional to the air flow in the vena contracta, and that fineness and homogeneity increase with distance from the atomiser head.

The spectrum distributions were also studied by determining the constants in the Rosin-Rammler probability equation and evaluating the standard deviation, the geometric mean deviation and Kramer's modulus [21].

Finally, a large number of laboratory tests was carried out to determine the influence of the grain-size distribution of secondary micro-mists on the agglomeration efficiency with various primary aerosol mixtures. The number of variables to be taken into account was considerable (concentration of primary aerosol, its electric charge and surface properties, shape of enclosure, velocities of dispersions, etc.). Some of the results obtained with an industrial type Aerojet Venturi are plotted in the form of Rosin-Rammler lines in Fig. 2.

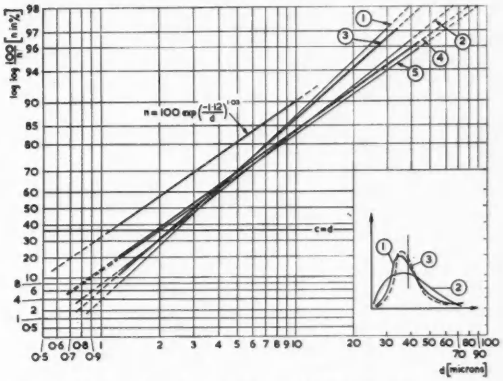


Fig. 2. Operation of an Aerojet with various micro-mists. Rosin-Rammler lines.

——— Secondary aerosols (surface-active micro-mists, σ = 36 dynes/cm).

▬▬ Primary aerosols (coal dust and silicate dust).

These results were obtained under the following test conditions: Flow of gases to be purified: 6,850 m³/hr; velocity at throat of Venturi: 64 m/sec (still better results could have been obtained at 110 m/sec using a more powerful fan); relative humidity: 82 per cent at inlet, 97 per cent at outlet; type of primary aerosol: solid silicate and carbon particles (mean diameter 2·3 μ); mass flow ratio (of liquid and dusts in the primary aerosol) approximately equal to unity; concentration of primary dusts: 5 gr/m³. Apparatus used: Aerojet Venturi with a single cyclone type collector unit.

The tests showed that the shape of the grain-size distribution curves (characterised by the coefficient b in the Rosin-Rammler equation) is decisive for the overall efficiency of the Aerojet and the collector unit. The insert in Fig. 2 shows as a dotted line "3" the frequency-distribution curve of a primary aerosol while the two solid lines "1" and "2" are the curves for two secondary aerosols. The agglomeration efficiency obtained with the micro-mist of type "1" was superior to that for type "2", although the geometric mean diameter of all three aerosols was very similar.

However, with increasing fineness of the primary particles the influence of coefficient b is reduced. The main factors for a good particle growth in the Aerojet under diffusion conditions are then (a) the mass flow ratio (which may be as high as 10), and (b) the time of contact (which may reach several seconds by reducing transit velocities in the convergent-divergent element and increasing the number of Venturi units ahead of the collecting apparatus).

INDUSTRIAL APPLICATIONS OF AEROJET PURIFIERS

A comparison of the performance of the Aerojet with that of other purifiers of conventional design has been published elsewhere [22]. There are, however, several other types of purifiers operating on similar principles. For instance, the Pease-Anthony Venturi Scrubber, developed in the United States, operates by injecting into the throat of a convergent-divergent

element a sheet-like spray of liquid at a low pressure (0·3-1 kg/cm²) which is broken up into a secondary mist by the high-velocity gas stream. Another flocculating apparatus of this class is the Rotojet Venturi (Swiss Provisional Patent No. 85,293 (1952)), in which the fine droplets of the secondary micro-mist are obtained by centrifuging action, with discs rotating at 10,000 to 100,000 rpm, either ahead of the convergent-divergent element (diffusion type) or at the throat thereof (impact type) [24]. This apparatus generates homogeneous micro-mists with very high *b*-coefficients which make it particularly useful for the wetting and precipitation of pigment nuclei of paints, with diameters of about 1 μ. These types of apparatus have the common feature that their agglomeration efficiency is mainly a function of the size and distribution of the particles of the primary aerosol.

A typical industrial application for sub-micron particles is that of an Aerojet Venturi followed by a cyclone collector for the agglomeration of ammonium chloride. The particles having a diameter between 0·09 μ and 0·3 μ, the collecting efficiency of the cyclone alone was evidently zero. With a mass flow of about 9 : 1, and a concentration of ammonium chloride of 0·18 gr/m³, the capturing efficiency of the combined system was 75 per cent of the weight of ammonium chloride passing through it. The agglomeration occurred with a preliminary diffusion action ahead of the throat of the Venturi, using a fraction only of the grain-distribution of the micro-mist, with a contact time below $\frac{1}{4}$ sec. A subsequent plexigum grid analysis showed that 75 per cent of the particles at the outlet had diameters of 0-1 μ and the remainder were between 1 μ and 3 μ. In terms of weight, however, more than 70 per cent had a mean diameter greater than 1·5 μ. As the cyclone collector had an efficiency curve which dropped off very rapidly below 20 μ, it was possible to determine the "growth coefficient" as $G = 20/1{\cdot}5 = 13$. The contact time from inlet to outlet was 0·4 sec. This compares with 17 sec for a sonic precipitator described by Saint Clair [25] in the United States, operating at 8·8 kc/sec, also with an ammonium chloride mist but with a higher concentration of 2 gr/m³. It should be noted, however, that for submicron particles without a preliminary diffusion action, the use of several Aerojet stages in series ahead of the final collector is necessary, in order to obtain a high capturing efficiency. An arrangement of this kind gave a capturing efficiency of more than 80 per cent with SO_2 mists [27], which was an exponential function of the quantity of liquid flowing per unit time. Another application dealt with the colloidal fumes of copper and its oxides [26], with electrically charged particles of about 0·01 μ diameter. These required high mass flow ratios and contact times of about 4 sec. It was found that hollow particles of similar size are more easily agglomerated, particularly if there exists some chemical affinity between the primary and secondary aerosols.

The equilibrium conditions provided by Gibbs' law make it difficult to reach efficiencies higher than 80 per cent for extremely volatile molecules. The trend in such applications is to combine the use of sonic or ultrasonic precipitators with micro-mist preparators. Efficiencies as high as 96-97 per cent have been obtained in this way by Fahnoe and his collaborators [28] with ethylene glycol vapours and aerosols of solutions of sodium chloride.

Thus, each application has to be regarded as a separate problem. It may be stated, however, that, for short contact times and impact action, the throat velocities of the gas flow must exceed 110 m/sec, with high turbulence, whereas for diffusion action and greater contact times velocities of 80 m/sec or less are adequate. Regarding energy consumption, it should be noted that the Aerojet Venturi installation consumes about 0·85 kWh per 1000 m³/hr of gases treated, compared with a minimum of 1·3 kWh for the water-screen apparatus.

Aerojet Venturi installations have been used in the following typical applications: Aluminium and oxides from aluminium paints, carbon black from heating plants (see Fig. 3), carbon and silica in mines, silica-aluminates from clay dusts, mists of glycerin solution from organic products, pigments from indigo fumes, condensation silica from refractory melting furnaces, etc.

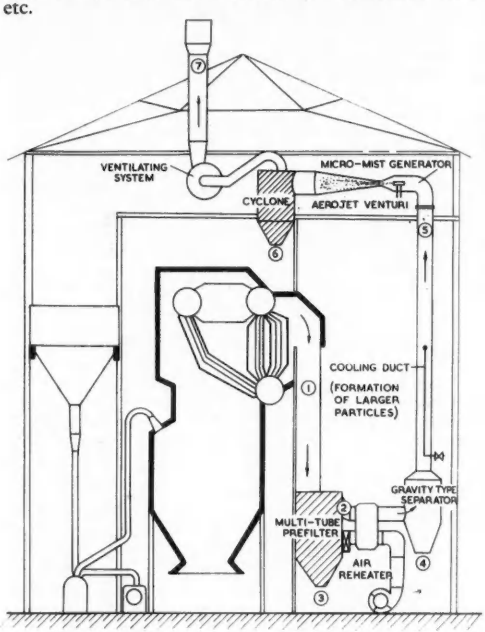


Fig. 3. **Schematic arrangement of a dust-purifying system for a power station (multi-tube prefilter and Aerojet Venturi).** (1) Entrance of gases to be purified (mean dust concentration 30 gr/m³, temperature 20° C). (2) Exit from multi-tube prefilter (dust concentration 8 gr/m³). (3) Dry recuperation of large-size carbon particles (80 per cent of the total weight of dusts is recovered). (4) Gravity type separator for recovery of non-evaporated water droplets and particles larger than 100μ. (5) Gas temperature ahead of Aerojet entrance is slightly below 100° C. (6) Fine dust particles with slight moisture content collected from single or multiple cyclone unit (19·7 per cent of total weight of dust treated) plus slightly alkaline solution containing SO_2 or SO_3 dissolved or combined. (7) Exit of purified gases containing a small percentage of SO_2 and about 0·2 gr/m³ of unburnt gases.

The use of multi-cyclone or multi-tube dust collectors in conjunction with electrostatic precipitators was suggested by Mühlrad [29] in a recent article, as a means of obtaining equipment capable of coping with high concentrations (above 30 gr/m³) as well as extreme values of grain sizes. Such combinations have already been developed in Great Britain and in the United States.

If an Aerojet Venturi is used in place of the electrostatic unit, in conjunction with a multiple-type preliminary collector, all the advantages enumerated by Mühlrad are retained, together with an appreciable saving in size and cost. Several Aerojet units, each with one or more cyclones in parallel, can be arranged, according to requirements, at the end of the purifying system. The total pressure loss is then about 150 mm water and corresponds to an energy consumption of about 0·5 kWh per 1000 m³/hr of gas treated. Although the mean consumption of an electrostatic purifier is 0·15 kWh, its cost is about three times greater and its normal useful life does not exceed 15 years, ac-

cording to Lee [30], so that the Aerojet-multiple cyclone equipment is definitely more economical.

Finally, it should be mentioned that the use of slightly alkaline micro-mists offers a new possibility for eliminating SO_2-dusts and micro-particles of sulphuric acids. A suggestion along these lines was publised by Kleinschmidt (Trans. A.S.M.E., 1941, pp. 349-356 and 363).

With an Aerojet operating under optimum condition (micron grain-size, concentration below 10 gr/m³), the quantity of particles allowed to escape is about 0·2 gr/m³. This corresponds to an overall efficiency of 99 per cent and is, therefore, better than that of electrostatic precipitation.

BIBLIOGRAPHY

(1) SELL, W. : *Forschungsheft*, 347, 1931.
(2) BRUN, E., CARON, R. & M. VASSEUR : *Gr. Rech. Aéron.*, Tech. Report No. 15, 1945.
(3) ALBRECHT, F. : *Physik. Zeits.*, Vol. 32, 1931, p. 48.
(4) BRUN, E. & M. VASSEUR : *C.R. Acad. Sci.*, 1944, pp. 636-638.
(5) BRUN, E. & M. VASSEUR : *J. Rech. C.N.R.S.*, Vol. 3, 1947, pp. 107-122.
(6) DEMON, L. : *Rech. Aéron.*, Vol. 1, 1948, pp. 15-19.
(7) HAEUSER, F. & G. M. STROHL : *Zeits. Tech. Phys.*, Vol. 4, 1924, p. 4 & p. 154.
(8) HOUGHTON, H. G. & RADFORD : Papers in Physics Ocean. & Meteo., M.I.T., Vol. 4, 1938.
(9) BRUN, E., DEMON, L. & M. VASSEUR : *C.R. Acad. Sci.*, Vol. 224, 1947, p. 1518.
(10) BOUCHER, R. M. G. : *C.R. Acad. Sci.*, Vol. 230, 1950, pp. 1826-1828.
(11) HATCH, T. & W. C. L. HEMEON : *J. Indus. Hyg. Tox.*, Vol. 30, 1947, pp. 172-179.
(12) SASS : *Kompressorlose Dieselmaschinen*, Springer, Berlin, 1929.
(13) NUKIYAMA, S. & Y. TANASAWA : *Trans. Soc. Eng.*, Vol. 4, 1938, p. 14, 86 & 138 ; Vol. 5, 1939, pp. 18, 63, 68 ; Vol. 6, 1940, pp. II-7, and pp. II-28.
(14) LEWIS, H. C., D. G. EDWARDS, *et ali* : *Ind. Engg. Chem.*, Vol. 40, 1948, pp. 67-74.
(15) ROSIN, P. & E. RAMMLER : *J. Inst. Fuel*, Vol. 7, 1933, pp. 29-36.
(16) LITTAYE, G. : *Gr. Rech. Aéron.*, Tech. Note No. 19, 1945 ; *Chaleur et Ind.*, Vol. 258, 1947, pp. 3-7.
(17) SAUTER, J. : *Forsch. Geb. Ing.-Wesens*, 1926, p. 297.
(18) HOUGHTON, H. G. : *Perry's Chem. Engrs. Hdbook.*, 1941, pp. 1894-1993.
(19) RAYLEIGH, Lord : *Proc. Roy. Soc.*, Vol. 47, 1890, p. 291.
(20) LANE, W. R. : *Ind. Engg. Chem.*, Vol. 43, 1951, p. 291.
(21) KRAMER, H. : *Trans. A.S.C.E.*, Vol. 100, 1935, pp. 798-838.
(22) BOUCHER, R. M. G. : *Rev. Ind. Chim.*, Vol. 1952, No. 416, p. 71-77 ; *Mines*, Vol. 2, 1952, pp. 125-141.
(23) JONES, W. P. : *Ind. Engg. Chem.*, 1949, pp. 2424-2427.
(24) WALTON, W. H. & W. C. PREWETT : *Proc. Phys. Soc.*, Vol. 62, 1949, p. 341.
(25) ST. CLAIR, H. W. : *U.S. Bur. Mines*, 1940, No. 3/400, pp. 51-61.
(26) MCCABE, L. C., CHANERY, A., *et ali* : *Ind. Engg. Chem.*, Vol. 41, 1949, pp. 2486-2493.
(27) JOHNSTONE, H. F. & M. H. ROBERTS : *Ind. Engg. Chem.*, Vol. 41, 1949, pp. 2417-2423.
(28) FAHNOE, F., A. E. LINDROS & R. J. ABELSON : *Ind. Engg. Chem.*, Vol. 46, p. 1336, 1951.
(29) MÜHLRAD, W. : *Génie Civil*, Feb., 1952.
(30) LEE, L. : *Conf. on Pulv. Fuel*, 1947, pp. 612-655.

RUSSIA

The Cutting of Metals with Sintered Alumina Tools

By P. P. GROODOV and M. P. TZYGANOVA. (From *Stanki Instrument*, No. 4, 1952, pp. 10-12, 9 illustrations.)

The results of tests on aluminium oxide base non-metallic cutting tool tips are reported in this and the following article. The two series of investigations were carried out independently by two different experimental establishments. Both teams came to the conclusion that under favourable circumstances these ceramic materials can replace carbide tips. Small cross-section of cut, absence of impact loads and suitable tool designs are essential. Thus, savings both in cost and in scarce materials are possible.

"THERMOCORUNDUM" (sintered alumina) has been experimentally introduced as a substitute for carbide to provide inexpensive cutting edges of high productive capacity. Thermocorundum does not contain any tungsten, titanium or cobalt.

Investigations by the All-Union Tool Research Institute and practical experience in a number of machine shops have shown great possibilities for thermocorundum cutting edges in the machining of light alloys and other non-ferrous metals, in the finish and semi-finish machining of steel and cast iron, and also in the machining of some non-metallic minerals.

Table I gives the physical and mechanical properties of thermocorundum in comparison with those of other tool materials. It is seen that thermocorundum has the hardness of tungsten-cobalt carbide tips. Its use as a cutting material is limited by its low strength in bending and compression. Hence, it should not be used for rough machining steel and cast iron. However, the ceramic industry should be able to produce a ceramic cutting material of better strength.

The thermal conductivity of thermocorundum is low compared with that of carbides, and this determines the technique of soldering and the design of thermocorundum tips as well as the conditions applying to their operation. Rapid heating and cooling of thermocorundum cause the formation of cracks, followed by pitting of the cutting edge and disintegration of the complete tip.

Shop tests have shown that the homogeneity and porosity of the thermocorundum tip largely determine its cutting properties. When a tool bit goes dark after lapping on a surface table lubricated with graphite and some paraffin, it reveals excessive porosity and reduced strength. This can be used as a criterion for scrapping sub-standard material. Suitable for use are only plates of thermocorundum, white in colour, which, when examined through a magnifying glass with a magnifica-

TABLE I.

Tool material	Designation	Physical properties		Mechanical properties		
		Heat conductivity λ kcal/cm sec °C	Density μ	Rockwell A hardness	U.T.S. in bending σ_b kg/mm²	U.T.S. in compression σ_c kg/mm²
Heat-treated carbon steel	EU 12	—	—	—	360	400
Heat-treated high-speed steel ..	R 18	0·05	8·73	83	370	380
Tungsten cobalt carbide	VK 8	0·14	14·45	88·5	140	330
Titanium tungsten cobalt carbide ..	T15 K6	0·065	11·01	90·2	115	400
Corundum		0·0055	—	—	—	—
Thermocorundum	Type 14		3·75	86-92	30	90-150
Medium carbon structural steel ..	45	0·1–3	7·8	—	140	—

tion of × 20, do not show any cracks. Cutting edges should be free from excessive pitting. An investigation of the wear of thermocorundum cutting edges has shown that wear takes place mainly along the top face. Only minor evidence of friction produced by the contact with the chip can be observed on the flank. According to the depth of cut, the admissible wear on the face is between 0·5 and 1·0 mm.

Research carried out by the Institute on the stability of the cutting edge has shown very large differences between different varieties of thermocorundum. The measure of stability is the time between regrinds determined by a wear of 0·8 mm. The conditions of the tests are as follows : the material machined is a medium carbon steel having a Brinell hardness of about 190. The depth of cut is 0·5 mm, the advance per revolution is 0·17 mm and the cutting speed is 120 m/min. Under these conditions the best type of carbide tip, namely, a titanium tungsten cobalt carbide, has a time between regrinds of 300 minutes and the best variety of thermocorundum of 530 minutes, whilst the worst type of thermocorundum does not stand up for more than 10 minutes. This research has shown that the most suitable side relief angle is 8-10 deg. A smaller angle reduces the time between regrinds. A larger angle may cause deformation of the cutting edge. The end relief angle can also be made between 8 and 10 deg. Owing to the low strength and the brittleness of thermocorundum cutting edges, the best results are obtained in rigid set-ups with a negative side rake angle of 10 deg. However, with a negative side rake, the cutting forces increase and may cause vibrations in operation. For this reason, a narrow land is ground at the cutting edge which forms a negative angle of 5 to 10 deg., but beyond this land, the width of which is made equal to the depth of cut, the thermocorundum tip is formed with a positive side rake of 10 deg.

The cutting edge can be straight or curved. Best results are obtained with a curved cutting edge, since this reduces to a minimum the depth of cut at the corners. The side cutting edge angle can be between 20 and 90 deg. It must, however, be realised that with an increase of the nose angle, the rate of feed must be reduced because thermocorundum tools stand up only to a limited cross-section of the cut.

With a straight cutting edge a nose radius of between 1 and 2 mm must be provided. The end cutting edge angle can be made between 10 and 15 deg. and the slope of the top face should be between 0 and 10 deg. The Research Institute recommends a design of cutting tools with tips held by the cutting forces (Figs. 1 and 2). This design simplifies the grinding of the cutting edge and the replacement of the tip. Cutting tool designs with mechanical clamping of tool bits also give satisfactory results (Fig. 3).

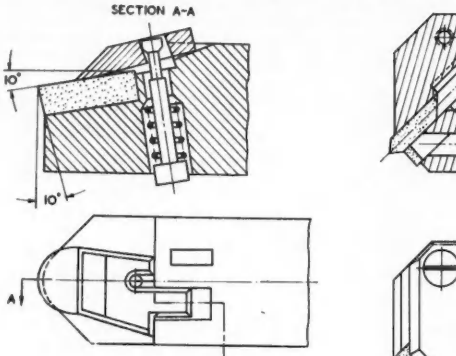


Fig. 1.

Fig. 2.

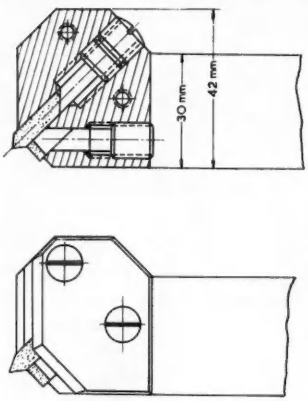


Fig. 3.

Thermocorundum tips are sharpened with grinding wheels of green carborundum using a continuous jet of coolant consisting of an aqueous solution of soda. Without adequate cooling, the effectiveness of grinding is considerably reduced. Rough grinding is carried out with wheels of 46 grit ; finish grinding requires wheels of 80 grit. The surface speed of the grinding wheel should be between 6 and 10 m/sec.

Thermocorundum bits are lapped on a cast iron plate with boron carbide powder of a grain size between 220 and 325 or with silicon carbide, both mixed with paraffin. The velocity of the lapping plate should be 1·5 m/min and the lapping pressure should not exceed 0·3 kg/cm².

Tests have shown that in the machining of steel and cast iron by thermocorundum tools, the depth of cut should be between 3 and 5 mm and its width about 0·2 mm. When the width is increased, the probability of shearing-off the cutting edges increases and soon becomes excessive. Recommended rates of feed in the turning of ferrous metals are given in Table II for different side cutting edge angles.

TABLE II.

Side cutting edge angle		20	30	45	60	90
Rate of feed mm/rev.	For machining steel of tensile strength σ_t = 65 kg/mm²	0·59	0·4	0·3	0·23	0·2
	For machining cast iron, Birnell hardness 190	0·88	0·6	0·42	0·35	0·3

For finish machining of steel, curved cutting edges are recommended which give good results up to a depth of cut of 1 mm and a rate of feed of 0·2 mm/rev. The surface quality obtained in the finish machining of steel with thermocorundum tools is good.

When the recommendations outlined above are observed, the time between regrinds of thermocorundum tips in the machining of steel (medium carbon com-

position, ultimate tensile strength 65 kg/mm²) is equal to that of titanium tungsten cobalt carbide tips. In the machining of cast iron of a Brinell hardness of 185, the time between regrinds is equal to that of tungsten cobalt carbide tips. Fig. 4 shows the influence of the depth of cut on the time between regrinds of thermocorundum tools with a curved cutting edge of 7 mm radius, in turning "steel 45" with a speed of 200 m/min and a rate of feed of 0·2 mm/rev. The time between regrinds is defined by a wear of 0·5 mm on the face. In Fig. 5 the effect of width of cut (or rate of feed) at a cutting speed of 90 m/min is shown. It is seen that the width of 0·2 mm is a critical point, beyond which the time between regrinds goes down steeply because pitting of the cutting edge takes place. Fig. 6 shows the relation of the time between regrinds to the cutting speed. The black circles refer to carbide tips, the open circles to thermocorundum tips. It is seen that a large scatter exists, and this is explained by the heterogeneity of thermocorundum tips. Both Figs. 5 and 6 show tests on medium carbon structural steel.

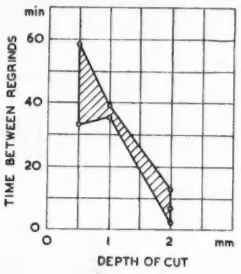


Fig. 4.

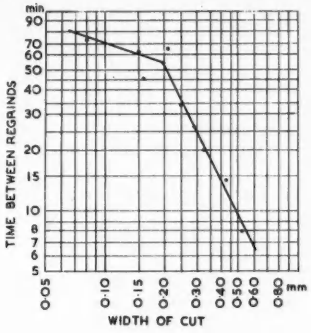


Fig. 5.

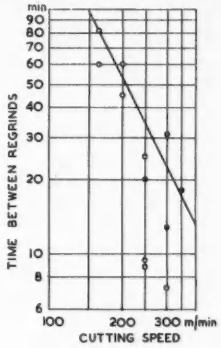


Fig. 6.

In turning with thermocorundum cutting tools it must be remembered that these tools cannot stand up to impact loads and cyclic forces. Thermocorundum cutting edges demand prior chamfering of the corners of the component. Rigid clamping and mounting of the component are essential, the clamping fixture must be properly balanced, the lubrication of the sliding surfaces of the lathe must be reliable and the wedges in the tool support slide must be adjusted for proper clearances. The surface to be machined must be as near as possible to the point of support of the cutting tip.

RUSSIA

The Employment of Ceramic Materials for Cutting Metals

By A. I. Isayev, N. N. Zorev and L. K. Kootshma. (From *Stanki i Instrument*, No. 4, 1952, pp. 12-14, 4 illustrations.)

The cutting properties of tool materials are determined primarily by their high-temperature strength. Whenever a tool material with a substantially higher strength at high temperatures is introduced, a sharp increase of cutting speeds and/or feeds follows. Thus, the appearance of high-speed steel and subsequently of carbide tips led to twofold and fourfold increases, respectively, of the temperature of the cutting edge. Correspondingly, the productivity of cutting increased by factors of 4 and 15, respectively, in comparison with ordinary carbon steel tools.

Some ceramic materials maintain a high strength even at the temperature of molten steel, and are therefore potentially ideal tool materials. Ceramics like other non-metallic minerals have little chemical affinity with metals and, hence, cause less friction in cutting; they have less tendency to cutting edge build-up and thus ensure a better quality of the machined surface. As a rule, mineral materials are relatively cheap and their use in place of high-speed steel and carbide tools is well justified by the saving in cost.

Preliminary tests have established that best results are achieved with ceramic materials based on alumina, which formed the basis for all subsequent tests reported here.

Fig. 1 is a logarithmic plot of time between regrinds against cutting speed as recorded in turning medium carbon steel. Graphs for cutting tools of high-speed steel and titanium-tungsten-cobalt carbide are shown alongside several ceramic materials. This diagram shows the superiority of a ceramic material designated ZM-332.

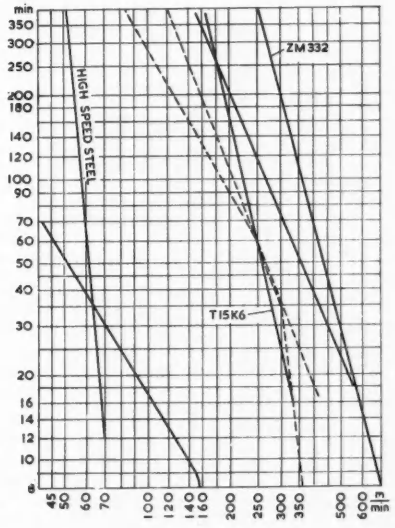


Fig. 1.

Detachable and fixed tool tips of ceramic material are used in cutting tools. Fixed tips are soldered or bonded in the recess of the tool holder. Brazing with copper, brass or a copper-brass composition can be carried out in oil or gas-fired brazing furnaces, in the same manner as the brazing of carbide tips. The main difference is the need to heat the brazed tips slowly before brazing and the subsequent slow cooling after brazing. These rules must be strictly observed on account of the relatively low resistance of ceramic materials to thermal shock. Thus, using a copper brazing process, the ceramic tips are heated in a slow-heating electric furnace up to a temperature of 900 or 1,000° C. The tool holders are also brought up to this temperature. After brazing, the tools are put into a furnace at a temperature of 700-800° C and are allowed to cool together with the furnace.

The bonding of tips to the holder can be used for tools operating with relatively small cross-sections of cut. The adhesive can be a silicate cement of the kind used for dental fillings.

In the design of tools with detachable ceramic tips the following principles must be observed. (1) The tip must be set in without exceeding an overhang of 0·7 mm. (2) The tip must be held in place by the cutting forces. Designs which have given good results in tests are shown in Figs. 2 and 3. The first design is distinguished by its simplicity and the second by the provision of a chip breaker and by its universal applicability. This type of cutting tool can be used for turning and facing operations.

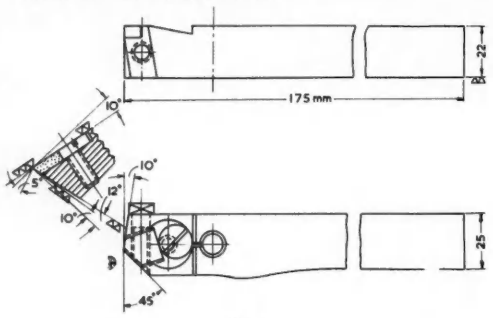


Fig. 2.

Cutting tools with detachable tips are preferred because ceramic tips can be separately ground. Smaller intervals between regrinds can be accepted and, therefore, higher speeds and feeds can be employed in cutting. In the tool design of Fig. 2 the time taken to replace the ceramic tip does not exceed 15 seconds.

The sharpening of ceramic cutting tips is carried out with grinding wheels of "green grit" carborundum. The use of cooling is highly desirable and greatly reduces tool grinding time.

Tools with fixed tips should be ground in two operations. At first, the tool holder is rough ground with a corundum grinding wheel, and subsequently the face of the tip is ground with a carborundum wheel. The flanks are not, as a rule, ground because the wear of the ceramic cutting edge takes place almost exclusively on the face. Detachable tips are sharpened separately in special grinding holders.

To avoid the cracking and pitting of ceramic tool bits, the grinding must be carried out with a well-balanced and trued grinding wheel. Best results are obtained in grinding at very low grinding speeds of the order of 1·5 m/sec. The cutting edges are lapped with cast iron wheels and boron carbide powder of 200-230 grit. The surface speed of the lapping wheel is also of the order of 1·5 m/sec. When the normal wear on the face does not exceed 0·8 mm it is recommended that ceramic tool bits be resharpened by lapping only. The sharpening operation including grinding and lapping should not exceed a duration of 3 minutes.

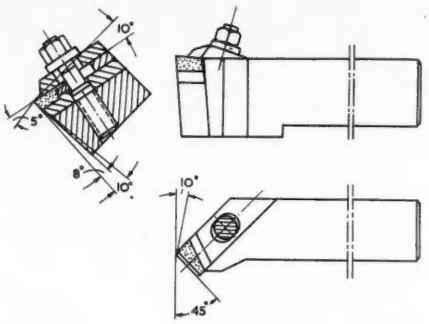


Fig. 3.

Many tests were carried out on the cutting of medium carbon steel with cutting edges having the following geometry: side rake angle $\gamma = -10$ deg; slope of top face $\lambda = 0$ deg; both relief angles $\alpha = \alpha_1 = 10$ deg; side cutting edge angle $\varphi = 30$ deg. end cutting edge angle $\varphi_1 = 10$ deg; nose radius $r = 0{\cdot}5$ mm. These tests revealed that up to a depth of cut of 2·5 mm the depth of cut has a much smaller influence on the time between regrinds of ceramic tools than the rate of feed. The reverse becomes true beyond a depth of 2·5 mm. Thus, the most profitable range of employment of the ceramic materials examined so far lies in finish and semi-finish machining. Investigations of ceramic tools at larger cross-sections of cut have shown that with 0·45 per cent carbon steel and a rate of feed of 1·0 mm/rev., depths of cut up to 5 mm can be permitted. For such steels, and a depth of cut of 3 mm, in the absence of impact loads and vibrations, the following expression gives the cutting speed which is based on a regrind time of 90 minutes. This expression applies to the ceramic material ZM-332.

$$v_{90} = 203/(s^{0{\cdot}37}\, t^{0{\cdot}19})$$

Ceramic tools have an optimum time between regrinds when obeying the following geometry: End relief angle $\alpha = 10$ deg; slope of top face $\lambda = 10$ deg; side cutting edge angle $\varphi = 30$ deg; end cutting edge angle $\varphi_2 = 10$ deg; side rake angle $\gamma = -10$ deg. A negative side rake angle and a small value of the side cutting edge angle φ cannot always be employed in spite of their beneficial effect. If the system comprising the machined component and the lathe is not sufficiently stiff, the side cutting edge angle may have to be increased to 60 deg. and the side rake angle reduced to zero or even positive values.

Measurements of cutting forces which arise in turning with ceramic cutting edges have shown that, other things being equal, these forces are somewhat lower than those occurring in cutting with carbide-tipped tools. This is explained by the lower coefficient of friction between ceramic materials and steel or other metals.

The surface smoothness obtainable with ceramic cutting tools is of the same order as that achieved with titanium-bearing carbide tips. Both give a much better surface than titanium-free carbides, which cause quite an appreciable amount of welding between the cutting edge and the work material.

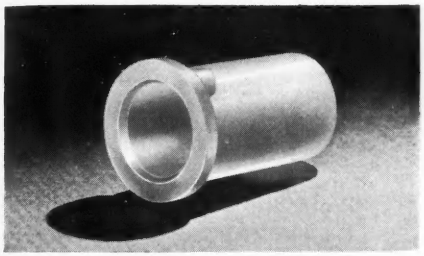
Ceramic cutting tools, it is claimed, are already used in the shop, where they have made possible an increase of the cutting speed in finish turning exceeding by 60-80 per cent the cutting speed now customary with titanium-bearing carbide tools.

New Materials, Processes and Equipment

NYLON BEARING BUSH REPLACES METAL

The Witton Moulded Insulation Works of The General Electric Co. Ltd. are now moulding in nylon small bearing bushes formerly made in metal for the wringers of washing machines. Reports from Wilkins and Mitchell, Ltd., the manufacturers of the washing machine, indicate that the change has proved satisfactory.

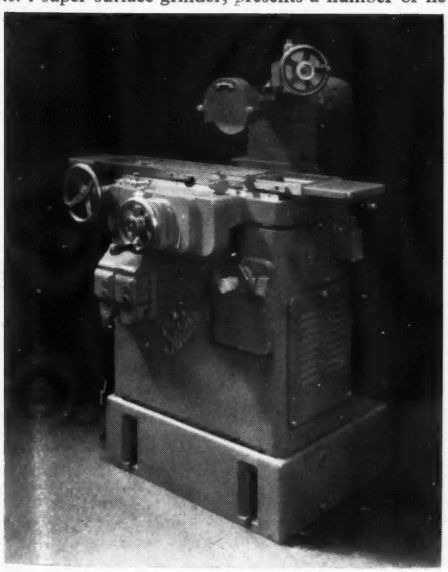
The change was made because lubrication by oil (which is necessary in a metal bearing) is not the ideal method on a washing machine, since the detergents used in washing soon disperse the oil. Nylon, on the other hand, is lubricated by water.



The bearings are injection-moulded in a 10-ton hydraulic press with an injection pressure of 7 tsi. The moulding cycle time is $\frac{3}{4}$ minute. The internal diameter of the bearing is $\frac{1}{2}$ inch.

SURFACE GRINDER

The latest machine to be added to the line of surface grinders manufactured by Arthur Scrivener Ltd., Birmingham, is one having a table with a working surface of 6 in. by 18 in., mounting a 7 in. × $\frac{1}{2}$ in. grinding wheel. This machine, which is known as the No. 1 super-surface grinder, presents a number of new features. In the case of any machine which produces finishes of the order which are becoming more and more required in this field, the spindle and bearings play a most important rôle. The No. 1 Super is fitted with rigid plain bearings of very similar design to those employed in the firm's centreless grinders. The spindle, which is in nitralloy, $1\frac{1}{8}$ in. diameter in the bearings, runs in an oil bath.



The table can be operated either by hand or hydraulically, the valve gear fitted ensuring smooth reversal and immediate control of speed, which is up to 66 fpm. Cross-feeds are either by hand or automatic, the feed in the latter case being controlled by a single handle giving forward or reverse feeds, or disengagement, at will. The large saddle cross-feed handwheel is calibrated in 0·001 in. divisions, but the micrometer feed fitted gives direct-reading increments of 0·0001 in.

The vertical rise and fall of the wheelhead is obtained by a handwheel situated on the wheelhead itself. Here, also, a fine-feed attachment permits of adjustments in increments of 0·0001 in. Lubrication of all working and sliding parts (except the spindle) is effected by a one-shot lubricator located at the rear of the machine.

SPARK-FIRED GAS ENGINE

Production of a series of four-cycle spark-fired gas engines is announced by Nordberg Manufacturing Company, Milwaukee 1, Wisconsin.

These engines, known as Types FSE-9 and FSE-13, are built with 9 in. and 13 in. bore sizes respectively in non-supercharged, intercooled-supercharged and " Supairthermal " types covering a range of 265 to 4260 hp.

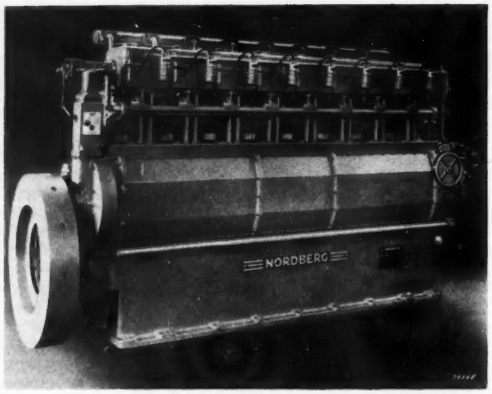
Both the Nordberg FSE-9 (illustrated) and FSE-13 engines economically burn natural gas, butane, propane, manufactured gas and sewage gas. Other gases of lower BTU content can also be used, but at reduced ratings. Where gas is available on a seasonable basis, the spark-fired gas engines have the advantage of being convertible to 100 per cent fuel oil operation.

The thermal efficiency ranges in excess of 41 per cent with the " Supairthermal " type engine and to 38 per cent with the non-supercharged engine. This high efficiency is the direct result of expansion ratios up to $12\frac{1}{2}$ to 1 and controlled air-fuel ratios by variable inlet valve timing.

To ensure smooth, uniform combustion, the correct air-fuel mixture is maintained by the precise timing of the inlet valve. The compression ratio can be selected to any desired value independent of the expansion ratio. For example, the " Supairthermal " gas engine has a clearance volume $1/11\frac{1}{2}$ of the total cubic inch piston displacement. At full load, the inlet valve may be closed at a point when the piston has displaced a volume only eight times greater than the clearance volume. This results in a compression ratio of 9, but the expansion ratio of $12\frac{1}{2}$ is maintained. As a result, the " Supairthermal " engine has the required low compression temperature to operate with minimum excess air without detonating and a high thermal efficiency due to the high expansion ratio.

The Nordberg gas engine can be operated without pre-ignition or detonation with a mixture having a small percentage of excess air. This is close to the chemically correct air-gas ratio, and combustion is rapid and uniform.

Two ignition systems have been employed on these engines. On the FSE-9 engines, a low-voltage impulse



type magneto with distributor, external coils, high-compression shielded spark plugs and low and high tension cables are used. One spark plug is used in each cylinder. The magnetos generate and distribute low-voltage current through the low-tension cables to individual coils adjacent to each plug. High-voltage current from the coils is then conducted to each spark plug at the proper firing interval of the respective cylinder. An impulse coupling on the magneto provides a hot spark at engine cranking speed and retards the spark automatically to ensure easy starting.

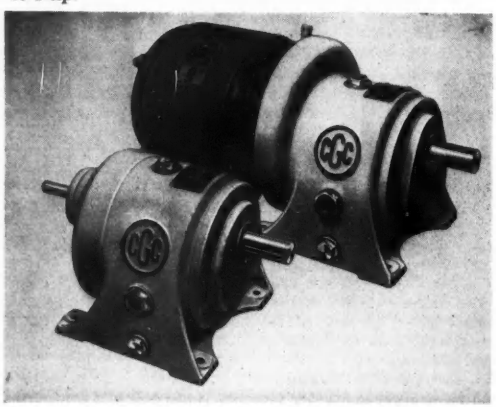
The ignition system used on the FSE-13 engines consists of an impulse generator, selenium rectifier which generates electrical impulses similar to a half-cycle of a conventional a.c. wave, transformer-coil and spark plug resistors. Two spark plugs are used in each cylinder and are mounted in water-cooled holders. The generator produces an ignition impulse which is accurately timed with the firing points of each cylinder.

GEARED MOTOR

To be known as Size 3 model, The Coventry Gear Company, Foleshill, Coventry, a member of the David Brown Group, have recently added a new unit to their range of geared motors.

This new unit, available in either double or triple reduction form, has an exceptionally wide range of application. It can be used for driving conveyors, small compressors, pumps, hoists, dryers, agitators, strainers, fans, textile machinery, etc.

With a motor speed of 1425 rpm, a choice of 17 output speeds, from 25 to 345 rpm, is available. The equivalent variation of input powers ranges from 1·25 to 5 hp.



Arrangements made for lubrication, oil level inspection, draining and refilling are such that these operations can be carried out in any of several mounting positions.

The gears and motors are integral and the unit height is very little greater than that of the motors alone. Thus, the unit is suitable for installation in confined spaces.

Weight (excluding motor) of the double reduction unit is 105 lb, and that of the triple reduction unit is 110 lb.

Any type of motor up to 14 in. diameter may be fitted ; alternatively, the gear units are available without motors (shown in the foreground of the illustration).

In moving the gear unit alone, the motor adaptors are replaced by modified covers, and the input and output shafts are co-axial.

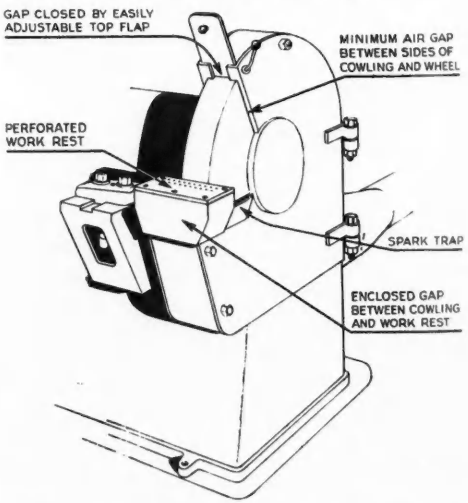
First reduction gears are of the simple helical type, second and third reductions are spur gears. All are precision-cut of high tensile steel. Maximum load on the output shaft is equivalent to a steady tangential load of 800 lb at a radius of 1 in. applied midway along the shaft extensions.

The gears are splash-lubricated. For vertical mounting, a screw pump is incorporated to provide positive lubrication to the top bearings and gears.

Overall efficiency is approximately 96 per cent for the double reduction type, and between 94 and 95 per cent for the triple reduction unit.

STEEL FOUNDRY RESEARCH IMPROVES GRINDING MACHINE EXHAUST SYSTEMS

Outstanding improvements in dust suppression on stand or pedestal grinding machines as used in steel and other foundries are announced by the British Steel Founders' Association. These improvements apply equally effectively to units having wheels of high (9000 fpm) and of medium (5400 fpm) peripheral velocity and can be easily fitted both to existing machines and to new equipment. They have been shown to give a considerable reduction in the amount of dust escaping into the foundry atmosphere when compared with conventional hood design.


GAP CLOSED BY EASILY ADJUSTABLE TOP FLAP
MINIMUM AIR GAP BETWEEN SIDES OF COWLING AND WHEEL
PERFORATED WORK REST
SPARK TRAP
ENCLOSED GAP BETWEEN COWLING AND WORK REST

Observations at the Dust Research Station revealed that air streams being drawn into machines of conventional design prevent dispersion within the cowling of the stream of dust-laden air produced by the grinding operation and cause it to adhere to and rotate with the periphery of the grinding wheel instead of being ex-

tracted through the exit-duct to the dust collector and fan system. The dust stream adhering closely to the wheel is thus caused to emerge from the cowling in front of the operator and subsequently to be deflected by the work-rest and by the work itself directly into the breathing zone of the operator.

By controlling the ingress of air being drawn into the cowling by the extraction system, and by concentrating the effects of extraction solely upon the dust-stream, it has been shown that it is possible to reduce very substantially the amount of dust-laden air rotating with the wheel and thereafter emerging and reaching the operator. The measures adopted involve the design of a work-rest such that the effects of the extraction system are applied directly to the underside of the work-rest itself, thus bringing the extraction as near to the source of dust-generation as possible.

Further modifications include reducing to a minimum the gap between the casing and the sides or flanks of the grinding wheel, together with an easily edjustable " gap-closer " at the point where the wheel amerges from the cowling immediately in front of the operator's face. This gap can be readily closed by the operator as the wheel wears.

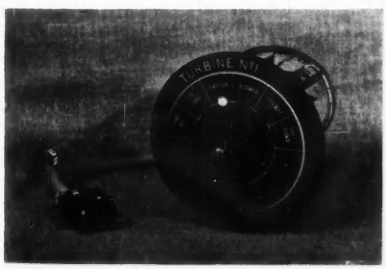
At the same time, the work-rest has been altered to embody either slots or perforations which, together with the suction applied below the work-rest, effectively prevent the work-rest acting as a stripping mechanism for deflecting the dust-stream towards the operator's breathing zone before it enters the cowling.

The modifications have been made in such a way that they have involved no complicated innovations or alterations to the construction of the stand grinding equipment. Only in this way could any design improvements evolved be applied retrospectively to existing machines at small expense and with the greatest possible speed. Similarly, in relation to new equipment, the manufacturer is enabled to introduce a marked increase in inherent efficiency of this and similar equipment with a minimum of departure from overall design, and with a minimum increase in cost of production.

"TELECOMMAND" SIGNALLING SYSTEM

A recent development in remote control and indication equipment by Standard Telephones and Cables Limited relates to a new signalling system for initiating stereotype orders between power station control rooms and boiler house and turbine rooms.

The system provides the control engineer with a means of selecting an order from a total of up to ten orders on which action is required in the boiler house or turbine room. The selection is made by means of a



specially adapted rotary selector switch, and initiated by depressing the switch knob after selection of the order required.

At the receiving end, a range of different types of receiver is available, suitable for mounting conveniently to the machine concerned. These include panel-mounting, wall-mounting, pedestal-mounting or hanging receivers.

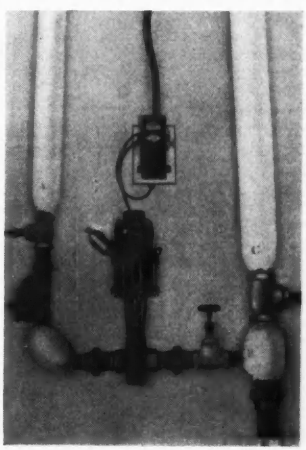
The orders are notified at the receiving end by audible and visual warnings by means of flashing illuminated engraved windows and Klaxon hooters. The receiver is equipped with an acceptance button which, when operated, will silence the audible alarm and render the order steadily illuminated on the receiver indicator panel. The sending switch in the control room is equipped with a lamp in the switch knob which flashes in unison with the receiver until such time as the acknowledgement or acceptance button is depressed on the receiver; the lamp in the sender switch knob then takes on a steady glow aspect in the same manner as the receiver. The control engineer is thus acquainted with the condition of the order in the boiler house or turbine room. The system can be supplied with both-way telephone facilities or with an emergency operation signal in the reverse direction. A 50-volt d.c. supply is required for operation of the system which is carried over multi-core telephone type cables of 20-lb per mile capacity.

Standard " Telecommand " systems of this type have been installed for the British Electricity Authority at several of their power stations, as well as at some power stations abroad.

HEAT CONTROL BY ELECTRONIC RELAY

The remotely controlled " Tem-Con " amplifier-relay manufactured by P.A.M. Limited, of Merrow, Guildford, Surrey, is designed to solve a great many problems of physical control. It is particularly suited for the efficient control of factory heating systems. Such an application is illustrated and described in the following. The motorised steam valve shown is operated by a remotely controlled Tem-Con amplifier relay. This system was substituted for the original mercury-steel bellows thermostat which, by its nature, could not operate effectively further than 20 ft away from the valve. The present control has a small bimetal sensitive make-and-break element suspended in the machine shop (15,600 sq ft, 18 ft high, heated by hot air ducts fed from a separate boiler house) out of any direct path of ducted air, and as free as possible from draughts from doors or windows. About 200 ft of twin bell wire suspended from the roof girders connected it to the steam valve, where a relay-amplifier was fixed; this unit controlled the current to the valve motor. The motor opens and closes the valve according to the dictates of the sensitive element in the machine shop which is set to operate at 61° F, and the ducts have been opened wide or partially closed in different parts of the factory to maintain uniform temperature.

The " on-off " control provided by the Tem-Con system proved superior to the previous modulating arrangement, mainly because of reduced time lag and reduction in the maximum boiler temperature.



The bimetallic element used with an electronic relay has many advantages because as low a current as 50μA is adequate, and the elements, being small and extremely sensitive, can be positioned almost anywhere.

The new installation showed an average saving in therms of about 34 per cent.

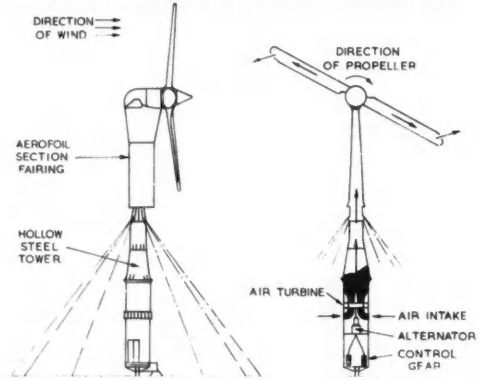
WIND-DRIVEN GENERATOR

An experimental wind-driven electric generator of 100 kW capacity designed and manufactured for the British Electricity Authority is nearing completion and will be erected and tested on a site, the location of which is still undecided. The contract has been secured by tender by Enfield Cables Ltd., the principal sub-contractors are de Havilland Propellers Ltd., and the English Electric Co., Ltd., and a number of other firms are co-operating.

It was found that the "depression" principle, tested on a small scale by Andreau in France, would produce electrical energy with a conversion efficiency slightly lower than could be obtained from orthodox wind power plants of equal size. On the other hand, the physical and mechanical advantages are considerable, and likely to increase as machines grow larger.

The depression principle employed results in an arrangement in which the generator is directly coupled to an air-turbine, both being near ground level and not mechanically connected to the propeller. The propeller, by extracting air from the system, sets up a pressure difference across the turbine sufficient to cause the latter to rotate.

The propeller has two hinged blades which are maintained at a mean coning angle of 5 deg. by torsion bar springs. The pitch is adjusted automatically by an hydraulic system so that the rotational speed is maintained constant when the wind speed is in excess of 30 mph and not more than 65 mph. The propeller blades are hollow and terminate at the trailing edge in an exit port for extraction of air by centrifugal force. Propeller orientation is power assisted and controlled.



The air-turbine is of the axial flow type single-stage design with a vertical axis, for a capacity of 50,000 cu ft of air per minute.

The synchronous 100-kW, 415-V, 3-phase induction generator is equipped with an exciter, which is started from rest as an induction motor.

To give an idea of the size of this installation, it may be mentioned that the tip diameter of the propeller is 80 feet.

THE USE OF CASTINGS IN AIRFRAME DESIGN

(*Concluded from page* 46)

The D-tube casting for the leading edge of an elevator for a fighter aircraft is shown in Fig. 3. This 356-T6 aluminium sand casting just meets the weight of the sheet metal structure—11·78 lb. If the portion aft of the D-tube were attempted as a casting, problems of metal flow would dictate a web thickness which would increase the weight over the combination shown by approximately 3 lb, and the tooling cost would be out of this world.

A sand casting can replace a sheet metal structure, as is illustrated by the wing leading edge of Fig. 4. This casting is equivalent in weight to a sheet metal component—and could well be even lighter.

Advanced types of design such as these are the aim of the airframe industry and will become more and more prevalent as research continues and costs become more realistic. Evolution is inevitable and it only requires a more concerted effort on the part of designers and founders alike to hasten it.

It should go without saying that the aircraft designer will use every available tool to reduce weight and production costs. Advances to date within the sphere of his activity are directly traceable to his demands for better and stronger products. If castings are to become more widely used, their quality must also improve and they must become more uniform from lot to lot.

CLASSIFIED ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns, are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

BLOWERS AND COMPRESSORS

Blade Adjustment in Axial-Flow Compressor Stages

By A. W. McCoy and A. V. Hooper. (From *Journal of the Aeronautical Sciences, U.S.A.*, Vol. 20, No. 1, January, 1953, pp. 43-48, 7 illustrations.)

An investigation of blade adjustment as a means of achieving volume regulation of an axial-flow compressor stage is presented. The effectiveness of such blade control is established and defined as the relative change of volume flow per unit of adjustment angle at constant pressure rise.

In the case of a grid element, the effectiveness of blade control is shown to be dependent upon the principal design parameters of reaction ratio, flow, and pressure coefficients. Low reaction ratios should be employed for stator-blade control, and for corresponding use of rotor-blade adjustment high reaction ratios are preferred.

Radial distribution of blade-control effectiveness is shown for several conventional stage types without consideration of radial equilibrium and non-uniform energy addition. In the case of stator grid adjustment, the distribution of effectiveness indicates maximum values at the blade root section—i.e., with the adjustment for increase in flow, the axial velocities tend to rise rapidly at the hub. Rotor-blade control in these conventional stage diagrams affords a somewhat more uniform distribution of effectiveness. Special stage designs for uniform spanwise distribution of adjustment effectiveness are also discussed.

MACHINE TOOLS

Hydraulically Boosted Pneumatic Clamping Fixtures

By P. G. Shalashov. (From *Stanki i Instrument, Russia*, No. 3, 1952, pp. 10-12, 4 illustrations.)

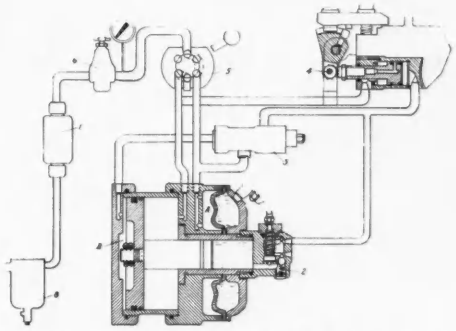
A drawback in the employment of pneumatic actuation for machine tool fixtures is the limited clamping force obtainable with the relatively low pressure of an industrial compressed air distribution system. On the other hand, the introduction of hydraulically actuated fixtures which can make use of much greater clamping pressures requires a special pump and hydraulic pressure system.

Hydraulically boosted, pneumatically actuated clamping fixtures fed from the normal compressed air distribution system escape both disadvantages.

The illustration shows, in semi-diagrammatic form, the main components of such an installation. It consists of a pressure booster (1), the supply valve (2) and equalising valve (3) of the clamping mechanism (4) actuated by one or more hydraulic cylinders, the control valve (5), reducing valve (6), non-return valve (7) and moisture separator (8).

The principle on which the hydraulic booster is designed is that the approach part of the clamping cylinder stroke is traversed against small loads by feeding hydraulic oil under low pressure. This enters the pressure line of the hydraulic circuit from a low-pressure reservoir *B* loaded through a diaphragm by compressed air which enters space *A*.

The high pressure in the hydraulic circuit is developed by means of a differential plunger system which



is actuated after positioning of the component and its light clamping by low-pressure oil.

Experience with an installation as shown has proved that the supply valve (2) is unnecessary. In some cases, the equalising valve (3) can also be dispensed with. These experiments have led to a standardised design in several sizes characterised by diameters of the pneumatic piston between 110 and 200 mm. Hydraulic pressures of 800 to 1,000 psi are obtained in the final clamping. Air consumption per cycle is between 0·20 and 1·25 cu ft.

MACHINING METHODS

Equipment for Surface Treatment and Drilling by the Electric Spark Method

By G. Barna. (From *Magyar Technika, Hungary*, No. 12, December, 1951, pp. 23-25, 6 illustrations.)

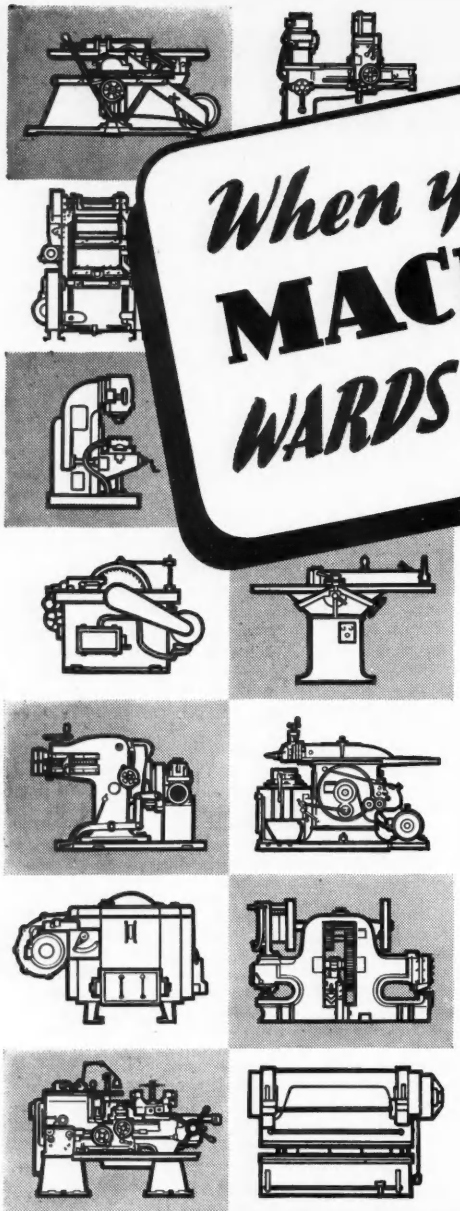
The Research Institute for the Steel Industry and the Technological Institute for the Machine Industry made extensive researches on the basis of Soviet researches and experiences in respect to coating by the electric spark method. A cutting tool made of carbon tool steel with martensitic texture was connected to the negative pole, and tungsten carbide material to the positive pole, with a view to obtaining a thin coat of the latter on the former. Capacitance, current intensity and voltage data were determined for a maximum retention of tool cutting power, ensuring spark discharge without arc generation and securing a good binding

EDITORIAL

(*Concluded from page* 41)

pressure, are laminated together, thus resulting in high bursting strength and freedom from pinholes. Indeed, it is hardly possible to produce single foils without some pinholes. Lamination entirely eliminates this fault.

More spectacular packing methods such as the "cocooning" or spray-protective packing system, may be known to engineers because they have received some publicity, but others may remain unknown although they may be of equal interest. Exhibitions such as the recent Packaging Exhibition are really suited for gathering information of potential value to the product designer which otherwise would involve him in more time and effort when a particular need for the information arises.



When you want... MACHINERY WARDS might have it!

No matter how difficult the supply position, there is always a good chance of getting the machinery you need at one or another of Ward's Depots—at Sheffield, London, Glasgow, Briton Ferry, Silvertown or Liverpool.

For obvious reasons we claim no more than a modest 'Wards might have it'—but so large are our stocks and so rapid our turnover that it is always good business to get in touch with Wards whenever you want machinery.

The 'Albion Machinery Catalogue' is a stock list of new and second-hand machinery revised and reprinted every two or three months. Ask for a copy to be sent to you regularly.

THOS W. WARD LTD

ALBION WORKS · SHEFFIELD

TELEPHONE: 26311 (22 Lines) • TELEGRAMS "FORWARD, SHEFFIELD"

LONDON OFFICE: BRETTENHAM HOUSE · LANCASTER PLACE · STRAND · W.C.2

G/30

of the coat to the base substance. A suitable apparatus was designed for the above mentioned purpose. The Institute for Mechanical Technology of the Budapest Technical University also carried out experiments with electric spark drilling, based on Soviet experiences. It was found that the automatic feed control—by means of a coil connected in series—of the drilling electrode, connected in this case to the positive pole, was the most reasonable. An apparatus was designed which can be built easily in the smallest shops and enables the drilling of 0·1 to 0·5 mm dia. holes with a 10 : 1 depth to diameter ratio in material of any degree of hardness, with copper or brass electrodes.

METALLURGICAL ENGINEERING

Changes in Structure and Properties in Connection with Arc Welding of Creep-Resisting Chromium-Molybdenum Steels

By T. NORÉN. (From *Jernkontorets Annaler, Sweden*, Vol. 136, No. 12, 1952, pp. 511-548, 47 illustrations.)

THE weldability of creep-resisting chromium-molybdenum steels with the principal analysis 0·15 per cent C, 1 per cent Cr, and 0·4 per cent Mo has been discussed from the metallurgical point of view, primarily with respect to the austenite transformation of the weld metal and the heat-affected zone and, secondarily, with respect to the notch sensitivity of the weld as well as of the heat-affected and unaffected base material. Moreover, the creep resistance of welded structures, the graphitisation problems and the oxidation resistance have been discussed.

The aim of the investigation was to determine welding conditions based upon sound metallurgical reasons and reasonable safety as regards the cracking risk in the weld metal and the heat-affected base metal. The main question has been whether there is any necessity of preheating and/or post-heating.

The studies concerning the austenite transformation have been based upon a typical TTT diagram and some Jominy curves of different charges. These studies have been combined with rather extensive microscopical examination of welded tubes. The microscopical investigations are necessary because of the difference in heating cycles between a weld and e.g., a Jominy test or test pieces used for obtaining TTT diagrams. It has been shown that welding without preheating can be permitted with 2·5 mm electrodes in the first layer in normal V-joints up to 8 to 10 mm plate thickness. Above this limit, preheating to 150 to 250° C is necessary to prevent martensite formation.

The notch sensitivity of the material discussed is of importance in connection with, e.g., root defects in a weld. This is especially true when martensite is formed. There is, however, good safety against brittle fracture if the structure is of the ferrite-bainite type.

The critical cooling rate seems to correspond to 8 to 9 mm Jominy distance. If this is known, welding conditions can be calculated.

The use of unalloyed electrodes for the first layer in a V-joint has been subjected to a preliminary study. This welding method is very favourable since the notch sensitivity of, e.g., unalloyed basic (i.e., lime ferritic) weld metals is very low. There is probably little risk of an influence on the weld strength at elevated temperatures if just a small part of the weld does not have the same analysis as the main part. On average, the weld metal of an unalloyed basic electrode used, as has been described above, will be influenced by the base metal analysis to such an extent that about $\frac{1}{3}$ of the base metal's chromium and molybdenum contents will be found in the first layer. Moreover, the oxidation resistance of this layer has proved to be surprisingly good and quite comparable with that of the base metal.

Finally, post-heating has been found to increase the impact resistance considerably.

WELDING

Effect of Stresses on Strength of Circumferentially Welded Cylinders

By L. J. PRIVOZNIK. (From *The Welding Journal, U.S.A.*, Vol. 31, No. 12, December, 1952, pp. 587s-595s, 20 illustrations.)

AN investigation has been made to determine the effect of residual stresses and stress relief on the mechanical properties of mild steel cylinders containing circumferential butt welds.

It was found that under high internal pressures, in cylinders in which the parent metal was of equivalent strength to the weld metal, the circumferential band of weld metal in the as-welded cylinder resisted the expansion and increased the bursting strength of the cylinder to a greater degree than did the band of weld metal in the stress-relieved cylinder. In cylinders in which the parent metal was of greater strength than the weld metal the circumferential band of weld metal had little or no effect on the expansion and bursting strength of as-welded compared with stress-relieved cylinders.

Circumferentially butt-welded cylinders with high longitudinal restraint had considerably lower ductility and somewhat lower strength than did similar cylinders with normal restraint when tested at — 40° F.

The effect of residual stresses existing in the weld metal is believed to be inconsequential, since the data indicate that the residual stresses can be relieved mechanically, during the first instance of loading over the as-welded yield strength, with no subsequent deterioration of mechanical properties.

X-RAY ANALYSIS AND TESTING

An Experimental X-Ray Apparatus with Midget X-Ray Tube

By P. J. M. BOTDEN, B. COMBÉE and J. HOUTMAN. (From *Philips Technical Review, Holland*, Vol. 14, No. 6, December, 1952, pp. 165-174, 15 illustrations.)

THE experimental X-ray tube described in this article is 45 mm long and 14 mm in diameter, including the earthed metal jacket. The X-rays are excited in a very thin layer of gold, deposited on a beryllium plate, which at the same time serves as exit window for the rays. The tube can be loaded with a voltage of 25 kV and a maximum power of 2·5 W. The half-value thickness of the radiation is very small, viz. 0·5 mm tissue at 25 kV and 0·3 mm tissue at 10 kV, owing to the small " inherent filter " of the tube (equivalent to 1·5 mm beryllium). Very high dosage rates of some hundreds of thousands of röntgen units per minute can be obtained, in spite of the very small power, and a rapid decrease of the dose in proportion to depth, owing to the fact that the focus can be brought within 1 mm distance of the area to be irradiated. The dose distribution across the irradiated area is very uniform; owing to the method of construction, the rays which pass the window obliquely are weakened more than axial rays, but this effect is more than compensated for by the natural directional effect of the continuous X-radiation, which is a consequence of its mechanism of origin, and is effective in the tube because of the extreme thinness of the gold layer.

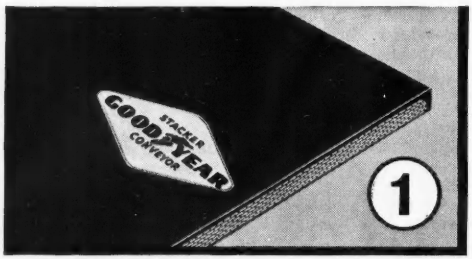
The X-ray tube is connected to the high-tension source by means of a flexible cable, 1·5 m long and 8 mm thick, with " Podur " insulation and earthed metal braiding. A low short-circuit current and a relatively small output capacitance are essential to avoid overloading of the very small tube in the event of a fault.

The generator of the apparatus is continuously adjustable for voltages up to 25 kV and currents up to 200 μA. The tube may be applied therapeutically, but it can also render good service in the testing of very light metals or very thin layers and for X-ray photographs of biological objects.

FOR HARD WORK AND PLENTY OF IT–

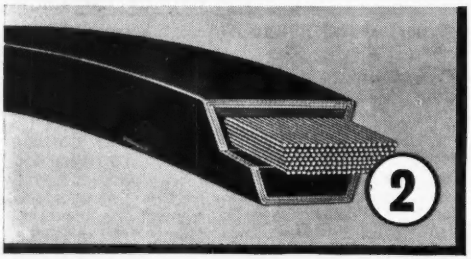
GOODYEAR BELTING AND HOSE

IN THE Goodyear range you will find conveyor belting for every type of service, transmission and V-Belts to suit every condition of loading, hose to meet every industrial need. Built with the accumulated knowledge of over 50 years' pioneer research and practical engineering, Goodyear Industrial Rubber Products give longer wear, more dependable service. And, above all, they keep operating costs to a minimum. That's why it pays to specify Goodyear.



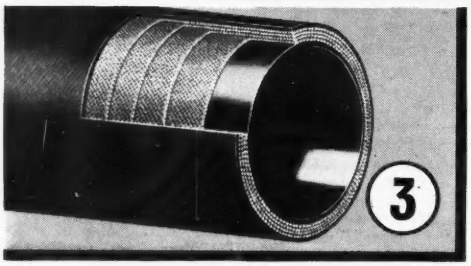
1 GOODYEAR CONVEYOR BELTS

The "Stacker" belt illustrated here is designed for installations which handle highly abrasive materials. Its tough resilient cover "gives" under impact and resists cutting. High grade bonding between the plies prevents separation under severe flexing. It is proofed against the ruining effects of mildew.



2 RAYON CORD V-BELTS

Goodyear Rayon V-Belts are ideal for all industrial drives, especially those longer, normal speed drives where shock loads occur. They stand up to sudden jolting loads that would break ordinary belts, for they contain strong, resilient, high-tensile rayon cords which "give" without snapping.



3 WRAPPED PLY HOSE

This Goodyear Hose is built from high-grade rubber tube wrapped in tough rubberized fabric for greater strength. A protective cover of bruise- and abrasion-resisting rubber assures lasting wear. And scientific arrangement of the fabric plies minimizes kinking. Intended for general service this wrapped ply hose gives long life under the most arduous conditions.

GOODYEAR

INDUSTRIAL RUBBER PRODUCTS

TRANSMISSION BELTING · V-BELTS · CONVEYOR BELTING · INDUSTRIAL HOSE

The Goodyear Tyre and Rubber Co. (Gt. Britain) Ltd., Wolverhampton

NEWS OF THE MONTH

PERSONAL

Dr. Thomas E. Allibone, F.R.S., has been appointed to the Board of The Edison Swan Electric Co. Ltd., 155 Charing Cross Road, London, W.C.2, in the capacity of director of research. Dr. Allibone will retain his position as director of the A.E.I. Research Laboratory, Aldermaston, Berkshire.

Mr. Howard Baron, A.C.A., F.C.I.S., secretary of Kayser, Ellison & Co. Ltd., Carlisle Steel Works, Sheffield, has been appointed a director of the Company.

Mr. G. W. Bone, M.A., works director of Davey, Paxman & Co. Ltd., Standard Ironworks, Colchester, has been appointed assistant managing director of the Company.

Mr. R. Boole, A.M.I.Mech.E., has been appointed technical manager of Brynmawr Rubber Ltd.

Mr. Joseph Brown, M.I.Mech.E., F.I.R.I., has been appointed chairman and managing director of David Bridge & Co. Ltd., Castleton, Rochdale.

Dr. Walter Cawood, C.B.E., is to be the Ministry of Supply's Principal Director of Scientific Research (Defence). He succeeds **Dr. O. H. Wansbrough-Jones, C.B., O.B.E.,** who, as already announced, succeeds **Sir Harry Garner, K.B.E., C.B.,** as Chief Scientist at the Ministry of Supply. The appointments take effect from 23rd February.

Mr. R. M. Garland, chief engineer of Veeder-Root Ltd., Dundee, has been appointed a director of the Company. In his new appointment Mr. Garland will be responsible for development, production and manufacture of the Company's products and will continue to act as deputy to the managing director.

Mr. T. Hall, Mr. E. Hepworth and **Mr. A. H. Royle** have been appointed directors of the Pioneer Oilsealing & Moulding Co. Ltd., Cottontree Works, Colne, Lancashire.

Mr. H. W. Hardern, Assoc.M.C.T., M.I.E.E., has been appointed assistant chief engineer of the Transformer Department of Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester 17. **Mr. E. L. N. Towle, B.Sc.(Eng.), M.I.E.E., M.I.Mech.E., M.I.Mar.E.,** has been appointed assistant chief engineer (industrial), and **Mr. F. B. Holt, A.M.I.E.E.,** consultant (industrial), in the Electrical General Engineering Department.

Mr. G. S. Helme, T.D., A.M.I.E.E., manager in Scotland for Lancashire Dynamo & Crypto Ltd., has retired after 21 years' service in that capacity, but will continue to serve as a consultant. **Mr. W. J. A. Gemmell, B.Sc.,** has been appointed to succeed Mr. Helme as manager for Scotland.

Mr. David Higgs, B.Sc., has been appointed managing director of Higgs Motors Ltd., Witton, Birmingham 6.

Mr. V. A. Higgs, B.Sc.(Hons.), A.M.I.E.E., A.M.A.I.E.E., A.F.R.Ae.S., has been appointed manager of the Aero and Auto Equipment Sales Department of the British Thomson-Houston Co. Ltd., Coventry. He succeeds **Mr. E. Sayers** who retired at the end of January after 20 years as manager of the Department, and a total of 48 years in the service of B.T.H.

Mr. James Hodge, M.A., A.M.I.Mech.E., A.F.R.Ae.S., Member A.S.M.E., senior consultant of Power Jets (Research and Development) Ltd., has left for the United States for four months. He will lecture at Columbia University on gas turbines.

Dr. S. G. Hooker O.B.E., D.I.C., F.R.Ae.S., has been elected a director of the Bristol Aeroplane Co. Ltd., Bristol.

Mr. O. W. Humphreys, director of the Research Laboratories of The General Electric Co. Ltd., left on the 13th January aboard the liner "Strathmore" for a business tour of Australia.

During the course of his tour he will lecture in Sydney to a joint meeting of the Institute of Engineers (Australia) and the I.E.E. (London). Members of the Institute of Physics, Royal Society, Institute of Production Engineers and Institute of Radio Engineers have been invited to attend. He will also lecture in Sydney to the Illuminating Engineering Society and in addition address various Engineering Societies and Institutes at Wollongong, Port Kembla, Hobart, and Melbourne.

Professor Willis Jackson, D.Sc., M.I.E.E., will join the Board of Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester, on July 1st, to take up full-time appointment as director of research and education. **Dr. C. Dannatt** has relinquished that appointment in view of an extension of his duties as assistant managing director.

Mr. F. W. King, M.I.D.E., works manager of the Streatham Works, and **Mr. R. D. Gaskin,** works manager of the Kennington Branch of Smith Meters Ltd., Rowan Road, London, S.W.16, have been elected to the Board of the Company.

Mr. A. D. Lidderdale, A.M.I.Mech.E., M.I.Prod.E., has relinquished his appointment with the A.P.V. Co. Ltd., of Wandsworth and Crawley, to take up the position of chief mechanical engineer to The Telegraph Construction & Maintenance Co. Ltd., Telcon Works, London, S.E.10. He will be responsible, under the directorship of **Dr. E. W. Smith,** for the management of the engineering division of the Company. Mr. Lidderdale, who spent the first part of his career with Leyland Motors Ltd., served during World War II with R.E.M.E., attaining the rank of Lieut.-Colonel and becoming assistant director of Tank Design.

Mr. Hubert G. Mason, sales director of C.A.V. Ltd., Acton, London, W.3, has been appointed joint general manager of the Company. Mr. Mason is also a director of Joseph Lucas (Export) Ltd.

Lt.-Col. E. A. Parr-Dudley, T.D., A.M.I.E.E., has taken over control and direction of home sales for Newman Industries Ltd., Yate, Bristol. **Mr. A. N. D. Kerr, A.M.I.E.E.,** has been appointed London sales manager of the Company at 49 Park Lane, London, W.1.

With the approval of the Prime Minister, the Minister of Supply, **Mr. Duncan Sandys,** has appointed **Mr. L. H. Robinson, C.B.,** who has been the under-secretary in charge of the Engineering Industries Division since 1948, to be a deputy secretary in the Ministry.

Mr. Herbert Smith has relinquished his office of managing director of British Ropes Ltd., Doncaster, but will continue as chairman of the Company. **Mr. Harry Smith** and **Mr. Alexander Smith Pearce** have been appointed joint managing directors, and **Mr. J. R. Dawson,** a director.

Mr. H. L. Thomas has joined the Hanwell Engineering Co. Ltd., Northampton, as general manager.

Mr. M. W. Thring, M.A.(Cantab.), F.Inst.F., F.Inst.P., has been appointed assistant director of Research of the British Iron and Steel Research Association, 11 Park Lane, London, W.1. He will continue as Head of the B.I.S.R.A.'s Physics Department.

Mr. P. Webb has been appointed manager of the London office of Laurence, Scott and Electromotors Ltd., Manfield House, Southampton Street, London, W.C.2.

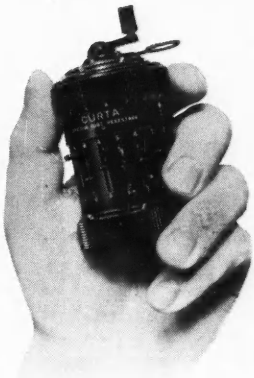
Mr. George Wilson, deputy chairman and managing director of Raleigh Industries Ltd., Nottingham, has been appointed a Governor of Loughborough College.

The Butterley Company Limited announce the following appointments to their newly-formed Oxygen Generator Division :—

Mr. H. W. Barnett will be manager of the new Division as well as act as the Company's London manager, the post he now holds. **Mr. A. A. C. Robertson, A.M.I.Mech.E.,** will be chief engineer, while **Dr. G. G. Haselden, Ph.D., D.I.C., A.M.I.Chem.E.** has been appointed consultant. Purchasing agent is **Mr. H. P. Williams.** Headquarters of the Division are at 20, Ashley Place, London, S.W.1. Tel. Victoria 8023.

CURTA....

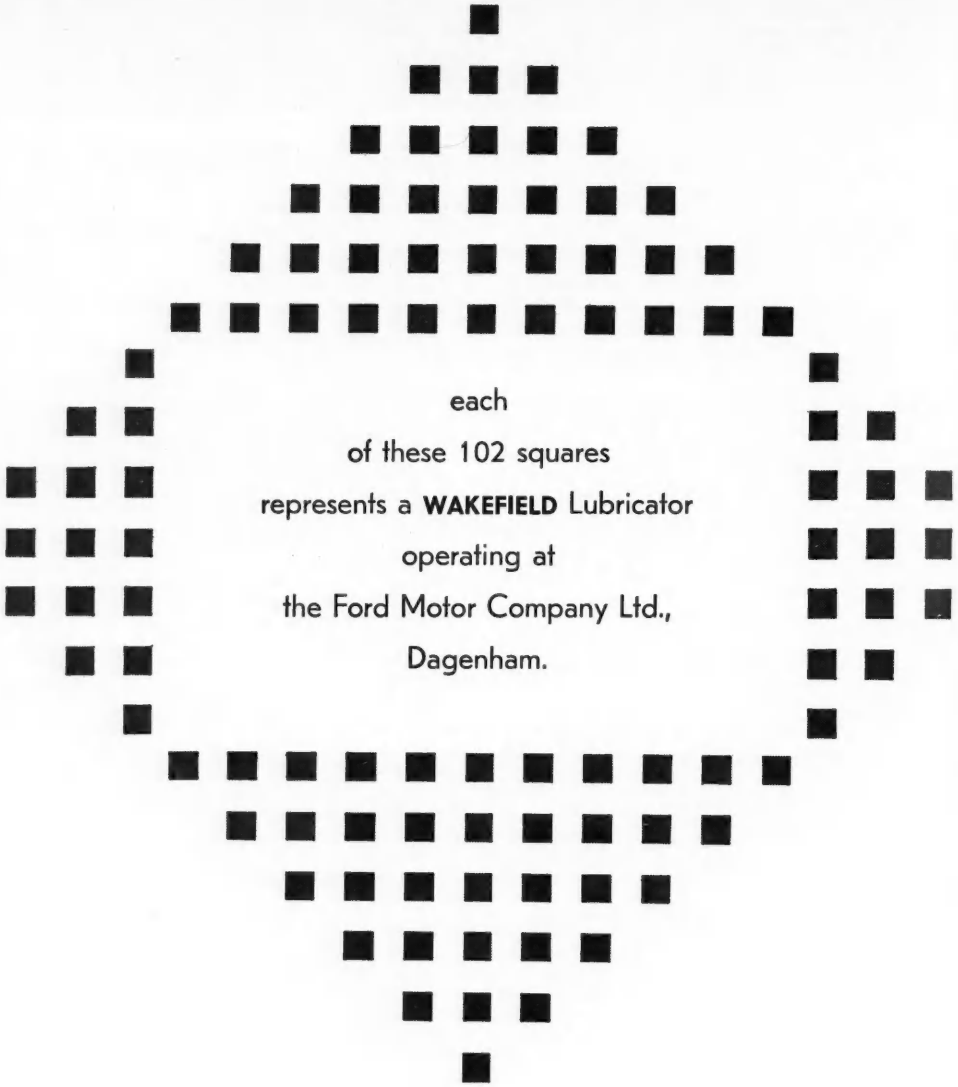
A NEW CALCULATING MACHINE DESIGNED ESPECIALLY TO SUIT the needs of the ENGINEERING INDUSTRY



Modern precision engineering often calls for greater accuracy than is possible by the slide-rule. The CURTA, with a capacity of 8×6 with 11 figures in the product register, is exactly what the Engineering Designer requires.

CURTAS are now proving their worth with Drawing Offices in more than 100 of the foremost engineering concerns in this country, as well as in many famous organizations on the Continent.

LONDON OFFICE MACHINES LIMITED
128 TERMINAL HOUSE, GROSVENOR GARDENS, LONDON, S.W.1. **Tel.: Sloane 1061, 1626**



WAKEFIELD
MECHANICAL LUBRICATORS

THERE IS A WAKEFIELD LUBRICATOR
FOR EVERY APPLICATION

ADMIRALTY INVESTIGATING PLASTIC BOATS

The Admiralty have been investigating the possibilities of the technique for building small boats of plastic material for several years and have been keeping in close touch with developments in the U.S.A.

About two years ago, the Admiralty purchased two fibre glass plastic dinghies. These have been subjected to trials, the results of which are fairly promising. Consequently it was decided to proceed with further investigations and to use the technique for boats of more complicated construction.

It is possible that the technique may prove more advantageous for the rapid production of large numbers of similar craft.

The investigation into this technique is further encouraged by the hope that plastic boats may be free of ship worm in tropical waters and that the trouble due to rot may be avoided.

MIRRLEES, BICKERTON & DAY LTD.

Members of the technical press were recently afforded an opportunity to visit the Stockport Works of Mirrlees, Bickerton & Day, one of the associate Companies of the Brush-ABOE Group.

The ever-increasing competition abroad has no doubt contributed to the Board's decision to concentrate their efforts on two new designs of oil engines which cover a wide range of technical requirements, are economical in operation, and can be produced at a competitive price. These new designs, known as the "J" and "K" series, are made in two forms, i.e., in-line and V-arrangement, with from 3-16 and 5-12 cylinders respectively, covering a power-range from 135-3,000 bhp.

Extensive reorganisation of the Works was initiated in October last year and, it is hoped, will be completed by next May. The lay-out of the Works has been drastically altered, and the fact that production actually increased during the difficult transition period is testimony to the efficiency and goodwill shown by all concerned.

One of the most interesting production processes demonstrated was carried out by a group of three machines which, between them, can perform in 40 minutes all the operations needed to produce a finished piston from the casting. A milling machine of the firm's own design for milling the V-shaped cylinder blocks was also of interest.

We understand that orders to the value of £12 million are in hand, and these are expected to be completed during the next 20 months.

PLASTICS MOULDING

British Productivity Team's Report

Mutual understanding between worker and executive is cited as one of the reasons for greater productivity in an American industry by a Productivity Team from the corresponding British industry in its Report just published.

The Team, drawn from the managerial, technical and workshop levels of the plastics moulding industry, spent six weeks visiting American factories in February and March of last year under the auspices of the Anglo-American Council on Productivity (now British Productivity Council) and of the Mutual Security Agency.

The progressive attitude of management, itself important, is conveyed to the American worker so effectively that he has a confidence in the future not matched by that of the British worker. The American believes that his future is tied up with that of his company, and that promotion from the lowest to the highest position is possible.

One matter which assists smooth relations is that in the plastics moulding industry agreements are on a plant or factory basis, which means that most union problems are speedily dealt with.

The incentive of goods available in the shops at prices low by comparison with wage levels strengthens the desire to make progress and earn more. Improvements in method are readily accepted as smoothing the way to greater productivity, lower costs, wider markets and more security, in *that* order, the industry relying on sales expansion to absorb labour released by the adoption of new methods.

Size of orders is a definite factor in permitting the installation of costly equipment, especially in finishing. The high living standards bring a high spending rate for the large population, but against this must be set the tendency for geographical areas such as New England, New York and the Middle West to develop their own moulding industry within correspondingly reduced markets. Broadly speaking, the Team found that very large orders do exist, but are less common than expected.

Piece-work payment is less common in American than in British industry, but the Team does not think this difference has a significant effect on productivity. On the other hand, shorter meal breaks and more shift-working—with more extensive transport, entertainment and shopping facilities for shift-workers—exercise a definite influence towards higher output. The attitude to safety is fundamentally different in the two countries, and while the American system has advantages, the Team does not believe its adoption here to be possible.

The Report contains comprehensive chapters on the techniques of thermoplastic and thermosetting moulding, with many illustrations, including drawings of machinery, and graphs.

In thermosetting moulding, which is one of the main branches of this, one of the younger industries, the Team found that America is not markedly in advance of Britain. American advantages lay in more extensive use of press control and in the variety of materials available.

In the other main branch, thermoplastic moulding, America is progressing rapidly, with machine size, controls of time and temperature and the availability of new materials notably in advance of those in Britain. Much of the activity is still in the development stage. The close attention of British moulders is urged.

The Team records its regret that the interchange between British manufacturers of ideas and of methods of designing moulds and tools have been hitherto restricted, and it is hoped that freer co-operation may soon be possible.

American equipment for finishing, assembly and packaging is of a high standard, with a noticeable tendency to mechanise finishing operations.

Ingenuity shown in adapting standard equipment to individual needs throughout the whole of the American industry was particularly admired by the Team.

The success of the American moulder in obtaining his customer's agreement to the modification of designs, in order to assist production methods, is noted.

The companies visited by the Team opened up their factories in a spirit of co-operation and on many occasions the discussions were undoubtedly of assistance to the Americans as well as to the visitors.

The Team presents its Report in the confident belief that everyone engaged in the British plastics moulding industry will find something of interest and value in its pages, and looks forward to discussing it in greater detail with anyone wishing to take advantage of the information obtained during the tour.

A public meeting to discuss the Report will be held in the Conference Room at the offices of the British Plastics Federation, 47-48, Piccadilly, London, W.1, on March 4, followed by meetings in Birmingham on March 25 and in Manchester on March 26. Everyone connected with the industry will be welcomed. Admission will be by ticket obtainable from the Federation offices.

BUSINESS NOTES

Autotrope Ltd., Old Sarum Works, Castle Road, Salisbury, Wiltshire, announce that the name of the Company has been changed to Salisbury Precision Engineering Ltd.

Monarch Tool Co. Ltd., manufacturers of high quality jigs and fixtures, sub-contract aircraft components, gear testing machines and special measuring instruments, Kirkheaton, Huddersfield, have changed the name of the Company to J. Goulder & Sons Ltd. The change has been made to prevent confusion which has sometimes arisen because of the similar names of other companies; it will characterise the independent nature of the business. **Mr. J. Goulder** is managing director of the Company.

Clarkson (Engineers) Ltd., Nuneaton, announce increasing demand for their Autolock and Dedlock milling chucks and cutters from Canada and the United States. With a Head Office in Toledo, Mr. F. H. Clarkson has established an American organisation to market these products in the main engineering districts of the U.S.A.

CHAPMAN & HALL

Just Out

THE CATHODE RAY OSCILLOGRAPH IN INDUSTRY

by

W. Wilson

D.SC., M.I.E.E., F.INST.P.

(*Manager, G.E.C. Development Laboratory, Witton*)

Fourth Edition Revised

8¾" × 5½" 288 *pages* 201 *figures* 36*s. net*

ELECTRICAL UNITS

With Special Reference to the **M.K.S. SYSTEM**

by

Eric Bradshaw

M.B.E., M.SC.(TECH), PH.D., M.I.E.E.

(*Prof. of Elect. Engineering, Faculty of Technology, Manchester University*)

8¾" × 5½" 64 *pages* 9 *figures* 8 *tables* 9*s.6d. net*

ELASTICITY IN ENGINEERING

by

Ernest E. Sechler

PH.D.

(*Professor of Aeronautics, California Institute of Technology*)

9¼" × 6" 419 *pages* 180 *figures* 68*s. net*

37 ESSEX STREET, LONDON, W.C.2

POWER!

for Industrial Purposes

Ford

ENGINE 12 HOURLY RATINGS

- **933 cc. PETROL (4 cyl.)**
  8 B.H.P. @ 1500 R.P.M.
  13·75 B.H.P. @ 2500 R.P.M.
- **1172 cc. PETROL (4 cyl.)**
  11·5 B.H.P. @ 1500 R.P.M.
  19 B.H.P. @ 2500 R.P.M.
- **1508 cc. PETROL (4 cyl.)**
  17 B.H.P. @ 1500 R.P.M.
  28 B.H.P. @ 2500 R.P.M.
- **2262 cc. PETROL (6 cyl.)**
  24 B.H.P. @ 1500 R.P.M.
  40 B.H.P. @ 2500 R.P.M.
- **3621·5 cc. PETROL (V-8 cyl.)**
  34 B.H.P. @ 1500 R.P.M.
  56 B.H.P. @ 2500 R.P.M.
- **3260 cc. PETROL (4 cyl.)**
  22 B.H.P. @ 1000 R.P.M.
  35·5 B.H.P. @ 1600 R.P.M.
- **3610 cc. VAPORISING OIL (4 cyl.)**
  22 B.H.P. @ 1000 R.P.M.
  34·5 B.H.P. @ 1600 R.P.M.
- **3610 cc. DIESEL (4 cyl.)**
  22 B.H.P. @ 1000 R.P.M.
  36 B.H.P. @ 1600 R.P.M.

Now a great new star joins the range of Ford Industrial Units—an entirely new 4-cylinder diesel engine capable of maintaining 34 B.H.P. continuously at 1500 R.P.M.

Full details of this and all other engines in the range are obtainable from our Industrial Units Dept.

DIEU ET MON DROIT

BY APPOINTMENT MOTOR VEHICLE MANUFACTURERS TO THE LATE KING GEORGE VI

FORD MOTOR COMPANY LTD · DAGENHAM · ESSEX

Thos. W. Ward Ltd., Sheffield and branches, have been appointed official general distributors of the "Staffa" Mobile Crane.

This is an extremely versatile general purpose crane which has a forward mounted jib, with its derricking action hydraulically operated, fixed in line with the chassis and counterweight to give maximum stability under all conditions of load and ground conditions.

Constructed to lift 2/3 tons, the "Staffa" has standard type car controls and the hydraulic lifting mechanism is finger tip controlled from the normal driving position.

With the jib horizontal the crane has an overall height of slightly more than 10 ft. In this position the lifting capacity is 1¼ tons, which adds considerably to the value of the crane for interior work—as, for example, the unloading of box rail wagons, etc.

Thos. W. Ward Ltd., Sheffield and branches, have been appointed official general distributors of "Wetherill-Hydraulic" Loading Shovels.

This loader has such sensitive scoop and side arm control that its use is not limited to shovelling and loading of loose materials: it can load and stack bales, barrels and other bulky items. Three scoop sizes are available, ¾ cub. yard, 1 cub. yard and 1¼ cub. yard, and maximum loads up to 1 ton can be carried.

Fitted with a dozer blade, the "Wetherill-Hydraulic" is capable of most levelling, piling and spreading jobs, and the Fordson Major Tractor to which the Wetherill mechanism is fitted affords ample power for all conditions of service.

The major points in "Wetherill-Hydraulic" design are:—

High discharge position and low headroom.
Constant power when engine is running.
Controlled discharge of scoop and rate of lift or lower.
Automatic cut out and overload control.

Hoover (Washing Machines) Limited have recently opened new laboratories at their factory at Merthyr Tydfil, Wales. They have been equipped with the most modern apparatus for metallurgical and chemical research and process investigation.

This move is part of the extensive building and development programme nearing completion at the factory, the biggest in Britain exclusively devoted to the manufacture of washing machines.

Mr. Andrew McDonald, chief engineer, is in charge of the laboratories.

The Industrial Diamond Information Bureau, 32-34 Holborn Viaduct, London, E.C.1, established in 1943, has collected from its initiation a large amount of publications falling into the fields of diamond occurrence and mining, diamond tools, diamond polishing, gemstones, crystallography and all related mechanical, physical and technological sciences. It was felt that this library could be more usefully employed internally, as well as externally, if a classified list of these publications were available. This has been done in this List which is classified according to the Universal Decimal Classification (UDC). It includes all accessions up to September 1952. Further accessions are listed in the monthly *Bibliography of Industrial Diamond Applications* issued by the same Bureau.

The list, comprising 214 pages and about 4000 titles, is for free distribution.

The British Thermostat Co. Ltd., Sunbury-on-Thames, has formed a new Company to be known as Teddington Industrial Equipment Ltd.

This new company will be exclusively concerned with instruments designed for use in heating, ventilating, air conditioning, process control applications and all instruments for the industrial field as well as The British Thermostat Company's recently developed range of I.C. engine control panels and shutdown units.

The background to the formation of this new company has been the considerable growth in the output of industrial controls by The British Thermostat Company which has required specialised staff and manufacturing facilities. The formation of this new company will achieve even greater specialisation and efficiency.

The directors of the new Company will include **Mr. J. E. Sherlock,** managing director, and **Mr. E. Burman,** formerly general sales manager of the parent Company.

The New World University Centre, 51 Eaton Place, London, S.W.1, is arranging courses in Trade Union Studies. The aim is to train working men and women at University level in the principles and elementary techniques of management and to increase their competence in their trade union activities.

THE PHYSICAL SOCIETY
37th EXHIBITION OF SCIENTIFIC INSTRUMENTS AND APPARATUS

The 37th Annual Exhibition of the Physical Society will be held at the Imperial College of Science and Technology, Imperial Institute Road, London, S.W.7, from Monday, 13th April to Friday, 17th April, 1953. A return has been made to the practice of former years of locating the whole of the exhibition in the main buildings of the College and this should be of great convenience to visitors.

Following the normal policy of the Society the great number of exhibits appeals primarily to physicists and much new and original equipment will be on show.

In 1953 again there is the inevitable growth of the use of electronic techniques in general laboratory and industrial instruments. The ubiquitous thermionic valve is still holding its own despite substantial inroads in its popularity in some fields made by cold cathode tubes and by crystal valves. Even in the field of research equipment, the trend is towards more complication and fully automatic equipment, enabling the modern research worker to concentrate his attention to the work in hand and not to be concerned with equipment whereby he obtains his results.

Among the many modern aspects of science dealt with in the exhibition are the problems arising out of high speed flight, industrial use of radio-isotopes and the applications of telecommunications and radar in modern travel.

FOURTH GAUGE AND TOOL EXHIBITION
MAY, 1954

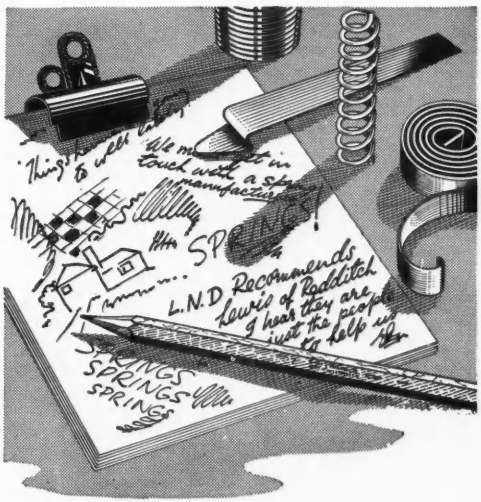
The fourth **Gauge and Tool Exhibition** to be organised by the Gauge and Tool Makers' Association of London, W.1, will be held in the **New Hall,** Elverton Street, Westminster, London, S.W.1, from May 17th to May 28th, 1954. The products on display will include gauges and measuring equipment; jigs, fixtures, and special tools; special-purpose machines; press tools; engineers' small tools; testing machines; moulds and dies; and diamond tools.

BRITTLE FRACTURE IN STEEL

The West of Scotland Iron and Steel Institute has arranged a One-Day Conference on Brittle Fracture in Steel to be held at 39 Elmbank Crescent, Glasgow, on Friday, 15th May, 1953. Papers have already been promised by the following:

Mr. W. Barr (U.K.)
Dr. S. L. Hoyt (U.S.A.)
Mr. N. G. Leide (Sweden)
Mr. P. Matton-Sjöberg (Sweden)
Mr. T. S. Robertson (U.K.)
Prof.-Ir. W. Soeté (Belgium)
Dr. C. F. Tipper (U.K.)
Dr. A. A. Wells (U.K.)

Arrangements are in hand and a more detailed announcement will be made shortly. In the meantime those interested in attending the Conference are invited to send their names and addresses to: The Secretary, West of Scotland Iron and Steel Institute, 39 Elmbank Crescent, Glasgow, C.2, so that they may receive individual notification of the final arrangements.



L.N.D. certainly knows what he is talking about. Lewis of Redditch design springs to do just the job you want, and they turn them out from top-quality materials so that they will last as long as your product. It might be worth while to have a word with us, don't you think?

LEAVE IT TO Lewis OF REDDITCH

THE LEWIS SPRING CO. LTD., Resilient Works, Redditch

Telephone: REDDITCH 720/1/2

London Office: 321 HIGH HOLBORN, W.C.I. Phone: Holborn 7479 & 7470

£1,000,000 ELECTRICAL EQUIPMENT EXPORT ORDER FOR BRITAIN

An export order valued at approximately £1,000,000 for the main electrical equipment for a big new iron and steel works in Spain has been placed with The English Electric Co. Ltd.

The equipment ordered includes a 7000 hp twin drive for a 42 inch blooming mill; a set of Ward-Leonard drives for the blooming mill auxiliaries and for the bloom shear; two 6,700 hp motors for driving the three stands of a 32 inch section mill, and numerous other auxiliary items of equipment.

Almost all of this equipment will be manufactured at the Stafford, Bradford and Liverpool Works of The English Electric Company.

The contracts have been placed by the Empresa Nacional Siderurgica, a company sponsored by the Spanish Government.

The new iron and steel works will be built near the estuary of the Aviles River in Asturias. The first stage will be in operation towards the end of 1956 or early 1957, and the output will amount to 350,000 tons of steel a year, which is almost half as much again as Spain's present total production.

Other important equipment orders for this new steel works, which together with the "English Electric" contracts amount to £6,000,000, have also been placed with engineering firms in this country through the Metallurgical Equipment Export Co. Ltd., representing a group of British manufacturers formed for the purpose of co-ordinating the export activities of its members.

MOND NICKEL FELLOWSHIPS

The Mond Nickel Fellowships Committee now invites applications for Fellowships of an approximate value of £900 to £1200 for 1953. Fellowships will be awarded to selected candidates of British Nationality with degree or equivalent qualifications to enable them to obtain wider experience and additional training in industrial establishments, at home or abroad, to make them more suitable for future employment in senior technical and administrative positions in British Metallurgical Industries. Each Fellowship will cover one full working year. Applicants will be required to state details of the programme they wish to carry out. Particulars amd forms of application are available from: The Secretary, Mond Nickel Fellowships Committee, 4 Grosvenor Gardens, London, S.W.1.

Completed application forms are required by 1st June, 1953.

Clarkson (Engineers) Ltd., Nuneaton, are distributing a speed and feed slide rule which for the first time enables operators to read both speeds and feeds for particular sizes of cutters without complicated calculators. They say that it is simple enough for a child to read. They are trying to ensure that it does become available to people on the shop floor and so are only distributing it direct against personal applications by milling foremen and operators and ratefixers. This method should make the slide rule a personal possession and so encourage their greater application.

The slide rule gives speeds and feeds for keyseating cutters and also for end milling operators with cutters from $\frac{1}{16}$" to 6" in both the Autolock and Dedlock range. This should meet a real need since the calculation of feeds and speeds for milling operators is probably one of the least understood parts of practical milling.

BRITISH STANDARDS

Adjustable Adaptors for Multiple Spindle Drilling Heads. B.S. 1935 : 1953 has been prepared to meet the need for these adaptors to be interchangeable not only between the various makes of spindle manufactured in this country, but also between British and American spindles. The specification goes a step further than American practice in that it provides dimensions for fine adjustment by two nuts in addition to the coarser adjustment by a single nut. Together with the dimensions, the standard lays down requirements for material and various manufacturing items. The adaptors specified are for Morse taper shank tools and are not intended for use with tools having parallel shanks. Price 2/6.

Hacksaw Blades. B.S. 1919 : 1953 represents the fruits of co-operation between the British Standards Institution and the British Hacksaw Makers' Association. Its provisions for the ranges of sizes, teeth and dimensions are identical with those accepted by American and Canadian manufacturers through agreements between the respective trade organizations. Price 3/6.

Classified Advertisements.

The rate for all classified advertisements is 6d. per word; in bold print 9d. per word; minimum order 6s. Box number advertisements 1s. extra. Instructions together with remittance must be received not later than the 3rd of each month for advertisements to appear in the same month's issue.

SITUATIONS VACANT

ARMSTRONG SIDDELEY MOTORS LIMITED, Coventry, have vacancies for Technical Assistants for research and experimental work on aircraft gas turbines; particularly on compressors, turbines and aerodynamic flow problems. Engineering degree, HNC or equivalent necessary.

Write in detail to Reference GWB1, Personnel Manager, **Armstrong Siddeley Motors Limited,** Coventry.

SMALL RESEARCH LABORATORY on hard materials requires engineering assistant with basic training, preferably B.Sc. standard. Knowledge in handling microscope and experience in micro hardness testing of advantage. Box I.D, 211.

MECHANICAL ENGINEERS required for the **G.K.N. Group Research Laboratory,** Birmingham New Road, Wolverhampton. Candidates should have an honours degree or equivalent and have completed a period of works training. Experience in any of the following fields would be an asset. Cold and Hot Working Metals, Machinability, Lubrication in metal working processes. Applications giving full details of qualifications and experience should be made to the Director of Research at the above address.

MACHINERY, ETC., FOR SALE

RECONDITIONED EX-ARMY HUTS, and manufactured buildings. Timber, Asbestos, Nissen Type, Hall Type, etc. All sizes and prices. Write, call or telephone—**Universal Supplies (Belvedere) Ltd.,** Dept. 50, Crabtree Manorway, Belvedere, Kent. Tel.: ERITH 2948.

INSTITUTES

MEMBERSHIP.—Every approved candidate graded in the Technical Engineering and Allied Classes (Administrative—Executive—Professional—Technical) is eligible for membership of **The Institute of Executive Engineers and Officers.** Admission fees reasonable. For application form and further particulars apply giving age, appointment or post held and Industry, to: The Secretary: Executive Chambers, 241 Bristol Road, Birmingham, 5.

MISCELLANEOUS

DEODORISERS AND AROMATIC COMPOUNDS for all technical and industrial purposes. **Gale & Mount Ltd.,** 37, Rothschild Road, Chiswick, W.4. Phone: CHIswick 6628.

WANTED.—Complete 1940 and 1941 volumes of "The Engineers' Digest" at double of original subscription price. Also Jan., 1949, and June, 1950 issues at 3/6 per copy.—Subscription Dept., 120, Wigmore Street, London, W.1.

ALUMINIUM FOUNDRIES. Gravity dies designed, manufactured and proved. Capacity immediate. **R. E. Ormerod Ltd.,** Ednall Lane, Bromsgrove, Worcs.

SUB CONTRACTS

WARNER & PARTNERS offer complete drawing office service. We can undertake design of electro-mechanical instruments, controls and light mechanical equipment. Alternatively, we offer the services of skilled designer-draughtsmen on clients' own premises. Tracing and printing capacity available. Prototype machines built to order.—Enquiries to **Warner & Partners,** regd. office, 29 Shelley Gdns., Wembley, Middlesex. ARNold 7993.

H. FORDSMITH LIMITED

HADFIELD STREET WORKS · CORNBROOK · MANCHESTER
TRAfford Park 1615-6